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A SPACESHIP IN ORBIT

MIR PUBLISHERS MOSCOW

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На орбите — космический корабль

Москва

«Педагогика», 1980

Scientists to Schoolchildren

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Translated from the Russian by
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MIR PUBLISHERS MOSCOW

First published 1984

На английском языке

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To Space Explorers of the Future

The prominent Soviet Academicians Nikolai Semyonov and Igor Petryanov in their address to the youth of our country wrote: "What lies ahead of you is the investigation of the crater-gnawed Moon and the landing on Mars. You are expected to penetrate into the hotbed furnace of Venus, install stations on the satellites of the big planets and probe the opaque atmosphere of Jupiter and Saturn. You are going to study the Sun, near-Sun and interstellar space, and then the innumerable stars. By examining them one by one you will learn that some of the stars are very much the same as the Sun, while others are quite different. Well, it is no use dwelling on how fascinating space research is, since you are craving to become spacemen yourselves."

Before you set out on your own explorations, however, you will have to become proficient in handling the technical means that are found to be indispensable for the purpose. You will have to do this not only to control the spaceships and stations already in use, but to create hitherto unknown spacecraft and roving vehicles to travel on the planets. This book acquaints the reader with the fundamentals of modern space engineering. It is a well-known fact that any progress can only be attained if we familiarize ourselves with what has been achieved by our predecessors.

In the Rocket and Out into Space

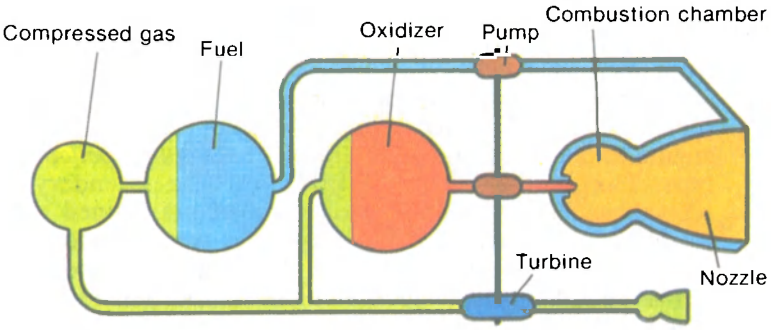
A large number of artificial satellites, or automated vehicles of various applications, are circling our planet. They have been carried into space by rockets. Man-made space probes are making their way to the planets of the solar system and far beyond it. They have broken free of the Earth's gravitation restraint by the same means, rockets.

We shall begin describing the rocket by acquainting our readers with its powerful engine. There is nothing so very complicated about it. The thrust force of a rocket engine results from the ejection of gases that are formed in the process of combustion. The more gas is ejected per time unit, the greater the thrust force becomes. It is possible to control the latter by changing the mass of gases, which leave the rocket per time unit, or the velocity of jet efflux.

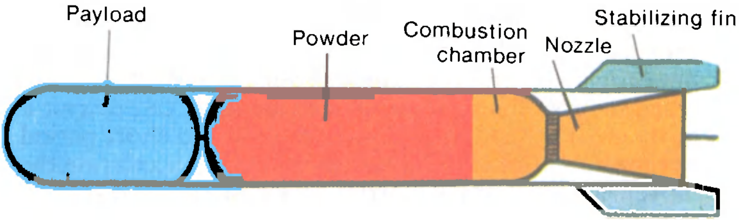
The rocket propellant is either liquid or solid. Accordingly, there are two types of rocket engines. First, let us discuss the *liquid-propellant rocket engine.*

The thrust is produced by the products of combustion. The combustion chamber is the main part of the rocket engine. In order that greater thrust could be created, combustion alone does not suffice. What we need here is a powerful and somewhat prolonged flash, a sort of delayed explosion. You must have seen how the stable flame of a splinter, when emerged into a jet of oxygen, flares up with a sort of blinding Bengal light. From this unsophisticated class-room experiment it becomes clear why there are two tanks in a rocket engine, one with fuel and the other with oxidizer. Liquid oxygen is used more often than any other oxidizer, while the products of oil refining or the compounds of nitrogen and hydrogen serve as the fuel.

The fuel and oxidizer are carried into the combustion



Liquid-propellant rocket engine



Solid-propellant rocket engine

chamber by centrifugal pumps or are driven into it by inert gases. The pumps are set into motion by a turbine, for which the gas is produced in a gas generator as a result of the decomposition or combustion of the matter contained in it, which in some cases is the fuel and oxidizer themselves.

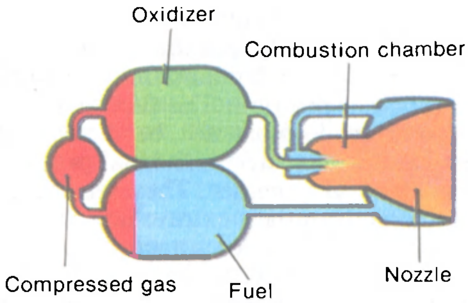
High-temperature gases are ejected from the combustion chamber through a propelling nozzle, the walls of which, as well as those of the chamber, are doubled. When the engine is set to work, the space between the

walls is washed by cooling components of the fuel. Thus, the "cooling jacket" prevents these parts of the engine from melting.

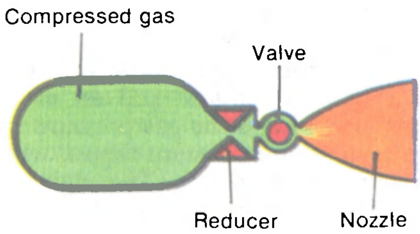
We began our discussion with the liquid-propellant rocket engine. However, it must be said that the first engine to come into use was that of the *solid-propellant* type. During the Second World War the legendary Katyushas, Soviet multiple rocket projectors, gained a world-wide renown. Their jet projectiles were provided with the kind of engine we are discussing here now.

The solid-propellant rocket engine is the immediate descendant of the well-known powder rocket and is by no means complex as far as its construction is concerned. The fuel, which in this case is a special rocket powder, is stored in the combustion chamber itself. The chamber with a propelling nozzle completes the structure of the rocket. In spite of its simplicity the solid-propellant rocket engine has a narrower scope of application than its opposite number. The solid-propellant rocket engines, when their size is sufficiently considerable, can deliver a fairly great thrust, but operate within a too short period of time. Occasionally they are employed to accelerate the movement of powerful carrier rockets immediately after they are launched. It should be mentioned here that this kind of take-off is usually accompanied by great over-loadings, which hinder the use of solid-propellant rockets for putting manned spaceships into orbit since in this case the flying conditions for cosmonauts are aggravated. However, space vehicles are provided with powder engines to secure a soft landing or in cases of emergency rescue. We shall discuss all this in detail and at greater length in the part of the book that comes next.

The heart of the rocket is its engine. Spaceships, orbital stations, planetary probes, and artificial Earth satellites are all launched into space by boosters provided with



Small liquid-propellant rocket engine



Gas rocket microengine

powerful rocket engines. The thrust they develop is fantastic. In space engineering large propulsion systems are used side by side with *low-thrust control engines*, which may well be regarded as scaled-down copies of more powerful engines. They work in exactly the same way, though some of the features are specifically theirs. For instance, the fuel supply system is much simpler: the fuel and the oxidizer are not pumped but displaced from the tanks by inert gases; several combustion chambers can be fed from the same tanks, etc.

Rocket engines can also be of the size that allows them to be placed on the palm of the hand. The thrust of such

microengines is small though by no means negligible. Sometimes it becomes sufficient for turning an artificial satellite or a spaceship and maintaining them for some time in the required position. The fact that there is no friction in outer space must not be disregarded here.

Designers have also created individual propulsion systems with small rocket engines. They are the ones that serve the cosmonauts in their extravehicular activity and are either carried by hand or attached to space suits.

The thrust of simpler microengines is produced by a jet of compressed gas. Metal bottles are filled with compressed nitrogen or air, and the high pressure makes it possible to have a reserve of gas, which though small in volume, is quite sufficient to make the engine operate for a considerably long period of time.

The tube connecting the gas bottle with the propelling nozzle has a built-in reducer and an electromagnetic valve. The reducer lowers the gas pressure so as to produce a more regular and constant thrust, while the valve ensures gas supply to the nozzle. The engine starts immediately (it is only necessary to open the valve). This is a highly important factor for the control of space vehicles, since any delay in the manoeuvre at a cosmic speed is hardly allowable.

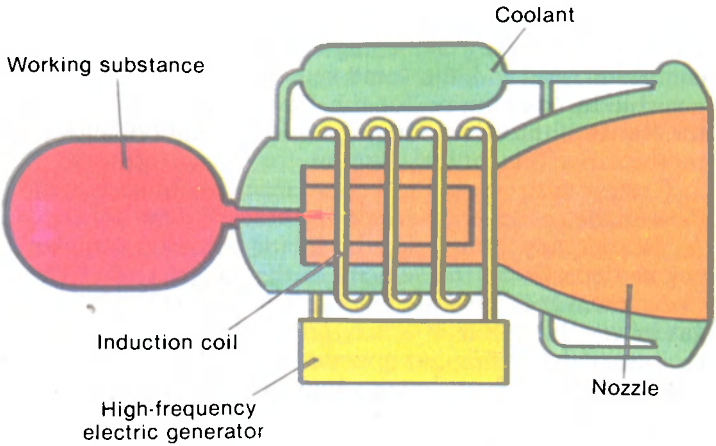
At present we already have microengines that work on the "solid gas". There are substances, such as the widely used (for domestic purposes) naphthalene or the ammonium salts that, when heated, are transformed from the solid into the gaseous state without passing through the stage of liquefaction. This process is known as sublimation. In order that "crystalline fuel" could be converted into gas, it is enough to have the heat produced by the vehicle equipment or by short pulses of electric current. However, it takes more time to start a microengine working on sublimable fuel than to fire an ordinary gas engine.

A variety of low-thrust engines enable the designer to have a free hand. By employing different types of control engines in one and the same space vehicle, it becomes possible to compensate for the shortcomings of one by the merits of the other. This kind of combination helps to produce perfect control systems for spacecraft.

There is every reason to believe that the future is with the *electric rocket engine* using a radically new concept. As has already been said, the thrust force of a rocket engine depends on the velocity of the gas jet efflux. The electric rocket engines are remarkable for the fact that the gas leaves the nozzle at a very great speed, which is not the case with engines that operate on the chemical energy of fuel. What we have here undoubtedly speaks in favour of the electric rocket engines. However, they require a substantial amount of electric energy which calls for the installation of a heavy power plant on a rocket, which, for the moment, is hardly feasible. Nevertheless, the first experiment prototypes of electric rocket engines have already been tested in space.

The most important units and components of the rocket. We have begun acquainting ourselves with the rocket by discussing its engine. But the carrier rocket contains quite a lot of units and components that are by no means less important. Let's discuss some of the most significant ones.

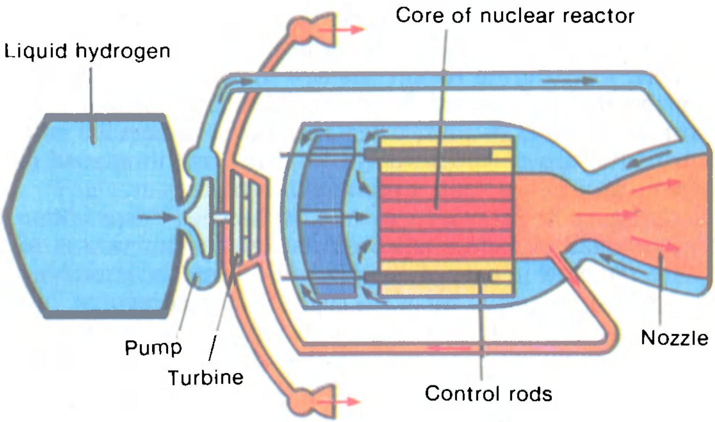
The rocket, as any other flying vehicle, should weigh little and be very strong at the same time. These two properties are not likely to be always compatible. In spite of all these obvious difficulties, it has been made possible to produce such craft. For instance, the huge fuel tanks were made to serve as the rocket body, and thus the problem of weight was, to a certain extent, alleviated. Special new alloys of higher strength have also been developed for the rockets.



Electrothermal rocket engine

There is not a single means of transportation that can do without steering. The rocket is by no means an exception. The early rockets had turning plates installed in the stream of gases discharging from the nozzle. The plates caused the gas stream to deflect, as a result of which the rocket turned. High-temperature gas could hardly be regarded as an appropriate working medium for even refractory metals. Hence, with some of the contemporary rockets the main engines can turn at a given angle with the help of universal joints (cardans), while with others special turning vernier engines are additionally installed. There can be several vernier engines in one rocket. Some of them can also be fixed. In this case during the manoeuvre the engines are ignited in a particular sequence.

Quite a few spacecraft consist of two or three rockets called stages. K. E. Tsiolkovsky called them "rocket



Nuclear rocket engine

trains". The stages of the multistage rocket work, as a rule, in a sequential order. It is the *first stage* that sets the "train" into motion. When all the fuel in it is exhausted, the first stage is separated from the rocket and falls down to Earth so as to decrease the mass left for the continuation of the flight. Then the engines of the *second stage* fire. They continue to boost the remaining parts of the rocket until the second stage itself falls away. The relay is taken up by the *third stage*. This stage (if it is a three-stage rocket) only carries what is called payload, i. e. the probe or the spaceship, and it is only this particular stage that attains the required cosmic velocity.

The last stage usually contains the instrument module. In it we find various instruments to control the flight of the rocket. It is from here that the commands are given to cut in or cut off the engines, to separate the stages, to change the rocket direction or to maintain the required flight velocity.

The top part of the rocket is always covered by the *nose cone*, which has a pointed form. It diminishes the atmospheric drag during rocket passage through denser layers of the atmosphere and decreases the amount of fuel used for the lift-off. Besides, when the rocket is injected into orbit the top cover protects the probe or the spaceship from air friction and excessive heating.

If the rocket carries a manned spaceship, there is one more small rocket installed on its top. Its function is to save the crew in case of an accident during the launching or during the initial leg of the flight. When necessary, this launch-escape rocket can carry the crew capsule away to a safe distance.

From the cosmodrome into outer space. New aircraft fly to their job by themselves. Ships cover the distance from the dockyard to the home port on their own. A rocket, however, along all its path from the manufacturing plant to the launching pad is only a passenger. Rockets are usually transported by railway. Cargo aeroplanes are too small for the purpose.

Now the stages of the rocket are delivered to the cosmodrome. From here the "rocket train" is setting out on its voyage into space. Let us cast a cursory glance at the panorama of the cosmodrome. The first thing that catches our eye is the huge assembly building where the rocket is assembled and checked out. Besides travelling cranes and trolleys the building houses a great deal of check-out equipment. Here all the units and components of the rocket stages are tested again and again, for one can never be sure that shipment and handling of the rocket did not cause any damage to it, however small. It should also be added that the testing of the systems responsible for the stage interaction during the flight can be only made if the rocket is fully assembled.

In the adjacent part of the building the spaceship is

subjected to exactly the same meticulous testing, for it can rendezvous the rocket only if all its on-board systems operate faultlessly.

And now the time has come for the specialists to say that everything is O.K. The spaceship is mated with the rocket and covered by the nose cone.

The transporter erector moves slowly along the cosmodrome. The rocket rests on the erector arm – a metal structure hinged to the transporter platform ... The train approaches the launching pad.

The transporter stops near a massive concrete construction. Its grey bulk reminds us of a dam. What we see now is the launching pad. The rocket is placed in the vertical position ready to start.

The hydraulic jacks of the transporter are actuated and the erector arm with the rocket gets off from the platform and rises slowly. Some time passes, and the rocket is lowered on to the upper part of the launching installation. Quite near to it, the umbilical tower and the service structure rise. The service structure encloses the rocket with platforms overhanging at various levels and accessible only by a lift. From the umbilical tower, thick bundles of electrical cables extend to the rocket hatches. There are sources of power supply on board the spaceship, but they will be required during the flight. Now, however, the power plant at the cosmodrome can supply the sufficient amount of energy for the final prelaunch tests of the rocket systems.

Soon the preparations will be completed. All the systems are properly adjusted and function faultlessly. The next step is particularly important for those concerned with the fuelling. From the underground storages the pumping stations begin to fill the rocket tanks with hundreds of tonnes of fuel and oxidizer (liquid oxygen). Liquid oxygen evaporates, and the rocket becomes wrapped with white clouds.

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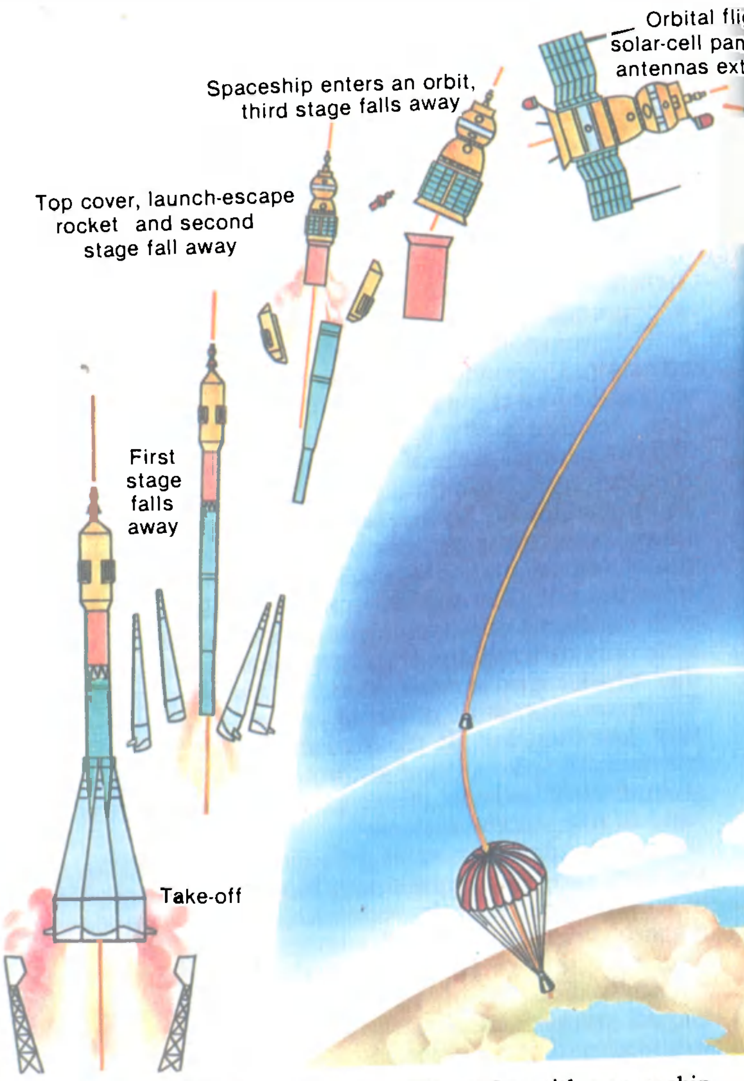
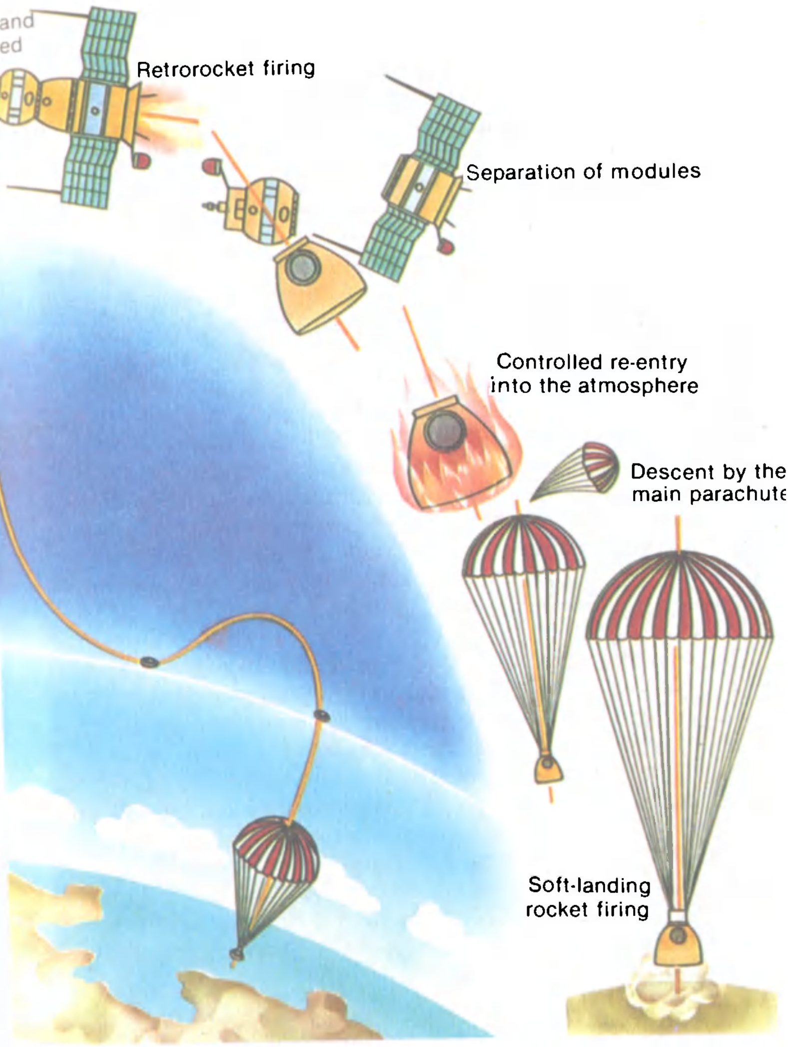


The flight profile of a multistage carrier rocket with a spaceship



Retrorocket firing
Separation of modules
Controlled re-entry
into the atmosphere
Descent by the
main parachute
Soft-landing
rocket firing

The launching is to take place in several hours. The cosmonauts are arriving. Brief farewells are exchanged, and they take their work places in the spaceship. The final check-outs begin, and not without the participation of the cosmonauts themselves. Less than two hours remains before the launching. The crew capsule is sealed. Now it is only by radio that the cosmonauts can communicate with the Earth.

The time-table of traffic in outer space is much more accurate than what it usually is on the Earth. If the departure of trains or planes is exact to a minute, at the launching pad it is a split-second that has the upper hand. Hence the importance of carrying out the work in accordance with a schedule and sticking to a given rhythm.

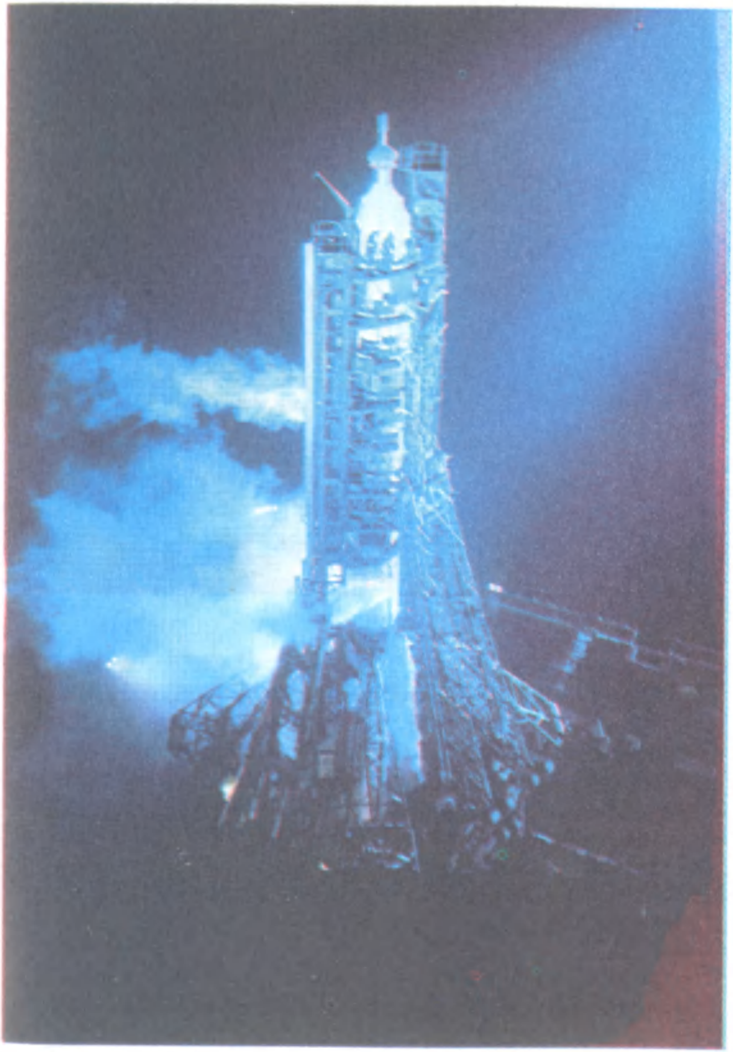
All cosmodrome facilities are well provided with special time-keepers forming the system of unified time. Its signals make it possible to synchronize the functioning of various services of the launching complex and the whole cosmodrome, register the exact on and off time for numerous instruments, installations, and mechanisms during prelaunch preparation, launching and flight of the rocket.

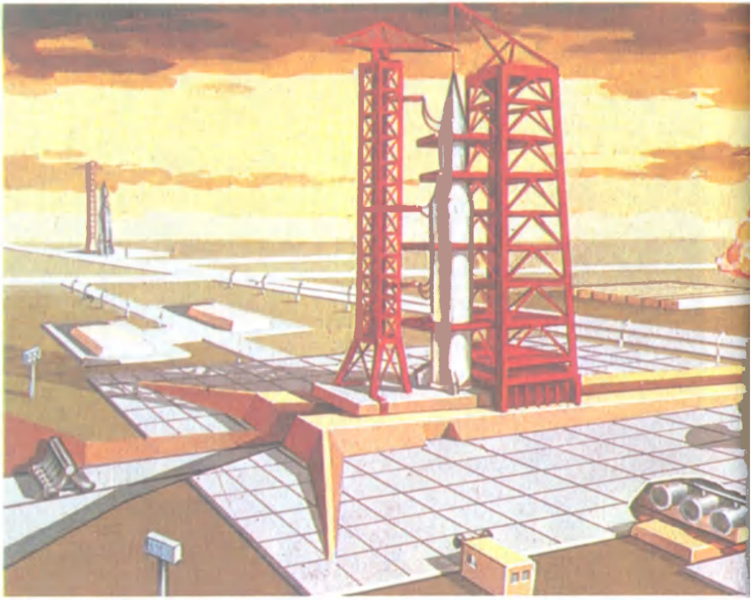
The preparations are over. The members of the launching team withdraw into a shelter. Five-minute readiness is announced. Now the control centre contained in a concrete blockhouse keeps the "reins of governing". On the television screens we see the cosmonauts looking at us with no trace of anxiety. The radio communication with them is being maintained non-stop.

The count-down reckons several seconds. The rocket is relieved of the service structure and umbilical tower.

And now the blast-off! The mighty roar of the engines is deafening. From under the rocket there comes what

Before the launch



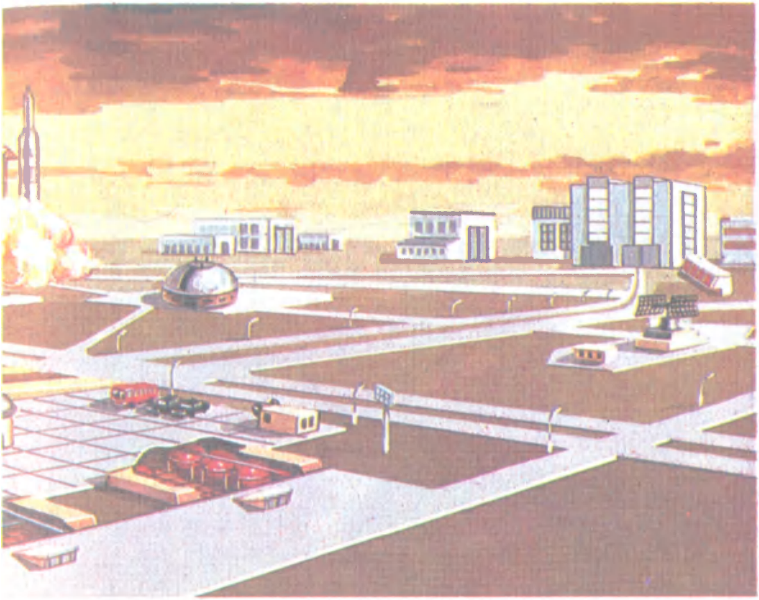


The cosmodrome

seems to be an all-devouring flame. Fortunately, flame deflectors are diverting the fiery gas away from the launching pad and the rocket. The engines have developed full power, and their thrust exceeds the weight of the rocket. Freed from the hold-down mechanisms, the rocket trembles and kind of reluctantly takes off from the ground and then shoots up into the sky.

A Spaceship in Orbit

Quite a few spaceships have already travelled in outer space though not much time has elapsed since the 12th of



April 1961, when the legendary Vostok piloted by Yuri Gagarin stormed space for the first time in the history of mankind.

All of spacecraft have much in common, which enables us to speak of the spaceship in general terms, just as we speak of the automobile or the aeroplane, without having in mind any particular make.

What is the spaceship built of? We will become acquainted with the spaceship by an example of Soyuz, the Soviet spacecraft that succeeded Vostok and Voskhod. The craft is 7.5 metres long and its maximum diameter is about 3 metres. It consists of three main sections.

In the *orbital module* the cosmonauts rest and do their research work during the prolonged orbital flights. It is here that a docking assembly is installed. This is necessary for linking up the spaceship with the orbital stations. The round hatch joins the orbital module to the *re-entry module*, in which the cosmonauts remain during the climb to orbit, dockings and re-entry.

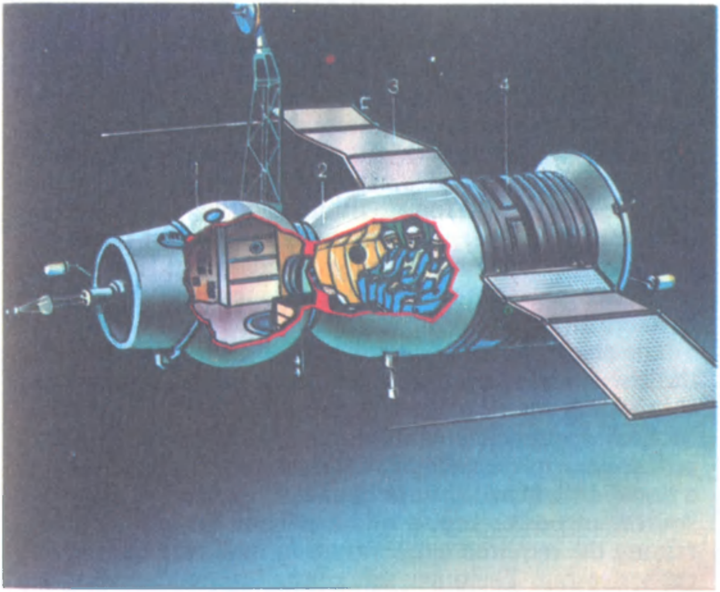
By closing the transfer hatch, the re-entry module is safely isolated from the orbital module. This makes it possible for the orbital module to be used as a manlock chamber, depressurizing it for the cosmonauts to walk in space. In the re-entry module there are special seats, in which the cosmonauts lie so as to cope with the overloadings during the lift-off and descent from orbit. For this purpose each seat is provided with a *contoured couch* to fit each particular member of the crew.

On both sides of the seat there are control handles by means of which it is possible to turn the vehicle round its centre of masses or to move it in space. There is also a handle to switch radio communication which makes it particularly handy when the members of the crew work in space suits.

The central control panel is in front of the cosmonauts. To the right and to the left of it there are command-warning devices. They can send commands and signals to the spaceship systems. The central control panel contains quite a few instruments. Let us take a closer look at some of them.

The work in space is time-ordered. Space watch does not merely show the time. It is also provided with a stopwatch which can be either set going or stopped. The fact is that the control of a spaceship is directly connected with a whole range of commands which must be generated at strictly regular intervals of time.

Here is another interesting device. It is a navigational globe. By watching it, we can always determine over what



The Soyuz spaceship:

1 – orbital module; *2* – re-entry module; *3* – solar-cell panel; *4* – instrument-assembly module

part of the Earth the spaceship is flying at the moment. The globe helps the cosmonaut to choose the landing place if it becomes necessary to discontinue the flight. The globe also serves as a reliable guide, telling the cosmonauts the time the spaceship enters and leaves the Earth's shadow. This is found to be highly important for conducting scientific research, for the orientation by the Earth's surface, etc. It is the same device that helps the cosmonaut know how many circuits have been made altogether and in what part of the circuit he is at present.

It is hardly feasible to describe all the instruments on the panel. However, it should be added that there are devices here which enable to monitor the process of closing and docking with the orbital station.

What the spaceship commander has on the central panel before him is a number of warning indicators of various colour. The green light shows that everything is fine, the yellow calls for attention, and the red signals distress. Besides, as a special contrivance to draw the attention of the pilot there are sound signals and flash-lights.

On the outside of the re-entry module there are engines to control the descent and soft landing.

The re-entry module is followed by a third section, or the *instrument-assembly module*. Here we have the spaceship's main engine and more than twenty smaller engines of final approach and orientation. There are also fuel tanks, systems ensuring a self-sustaining flight, as well as a docked flight with the orbital station. Here too are the sources of power supply and a part of the system maintaining the required temperature in the living quarters of the spaceship. The outer side of the instrument-assembly module carries solar-cell panels (not with all Soyuz spacecraft), antennas, and a radiator of the thermoregulating system.

Now we can go a little bit deeper into the spaceship systems.

The power plant in space. When orbiting, Soyuz may well be compared to a soaring bird. The resemblance is enhanced by the "wings" of spread panels of solar cells. To keep the systems and devices at work it is necessary to have a regular power supply. The solar cells transform the energy of sunlight into the electric power. The chemical storage batteries are applied for the same purpose, when the voltage in the spacecraft-borne supply line goes below a certain level. The automatic devices connect the

solar cells to the storage batteries and thus the power resources are made up for losses.

The system of power supply does not terminate to function even when the re-entry module touches down. Before the search-and-rescue team arrives it goes on with energizing the radio receivers and transmitters, life-support systems, light beacons helping to locate the spacecraft.

Recently, fuel cells have become sources of power supply in some of the spacecraft. In these unusual galvanic cells the chemical energy of the fuel is transformed into the electric power without burning. The fuel, hydrogen, is oxidized by oxygen. The reaction yields electric current and water. Later, the water thus produced can be used for thermoregulating or for drinking.

Along with high efficiency, this is an extremely important property of the fuel cells. The capacity of fuel cells is 4-5 times greater than that of storage batteries, though the fuel cells are not devoid of defects, the greatest of which is the weight.

The same reason hinders the use of atomic batteries. The radiation protection of the crew would make the spaceship too heavy.

Attitude control system. On separating itself from the last stage of the booster rocket, the inertia-driven spaceship, at a high speed, starts to rotate in a haphazard manner. It is hardly possible to tell where the Earth or the sky is. In the tumbling capsule, the cosmonauts find it very difficult to take their bearings, and it becomes impossible to continue the observation of celestial bodies. The work of the solar cells also becomes impossible. Hence, the spaceship is made to secure a particular position in space, in other words, it is driven to a desired *orientation*. When astronomical observations are conducted, the orientation is based on the brightest stars, the Sun or the Moon. To

receive energy from the solar cells, their panels have to be turned to the Sun. The rendezvous of two spaceships calls for their mutual orientation. Manoeuvring is also made possible only in the orientated position.

Various devices are used to orientate a spaceship or a station. One of them, a sighting device using the position of the visible Earth's disk, helps the cosmonaut to determine the angular deviation from the local vertical, or the line joining the centre of the Earth with the centre of masses of the spaceship. The local vertical can be constructed by means of another device, viz. the infrared vertical. Its function is based on the comparison of the Earth's temperatures with those of outer space.

The spaceship is equipped with a number of small jet engines of the altitude control system. By cutting them in and off in a particular order, it becomes possible to turn the spaceship round any of its axes.

Let us bring back into our minds the school experiment with a device which works on the same principle as a rotary lawn sprinkler. The reactive force of the water jets shooting out of the oppositely bent ends of the pipe suspended on a string, makes the device rotate. It is exactly the same with the spaceship, which is perfectly suspended – in weightlessness. Not more than a couple of microengines with oppositely directed nozzles would suffice to turn the spaceship round any axis. When several engines are fired in a particular combination, they make the ship acquire various positions, and not only that. They lend it additional acceleration, or deviation from the initial trajectory.

But "low thrust" is sufficient only for manoeuvres on a small scale. When it becomes necessary to introduce a more considerable change in the trajectory, a more powerful engine has to operate.

The routes of the Soyuz spaceships lie at heights of 200-450 km above the Earth's surface. In the long-

duration flight, the spaceship, even in this highly rarefied atmosphere, experiences a gradual air braking and begins to descend. If no measures are taken, Soyuz will re-enter denser layers of the atmosphere much earlier than scheduled. That is why the spaceship is regularly made to raise its orbit using the primary propulsion system (correcting-and-braking engine). The engine works not only for the spaceship to move up to a higher orbit, but also to approach for docking, manoeuvre in orbit or decelerate before landing.

The orientation is a highly significant part of space flights. However, the spaceship should not only be orientated, it is quite essential for it to be stabilized, or maintain a certain position. It is by no means easy to achieve this in space lacking in any kind of support. One of the simplest methods of stabilization is to attain it by spinning. What is taken into account here is the property of spinning bodies to preserve the direction of spin axis and to resist any disturbances. (We all know the top – a children's toy – remarkable for its "reluctance" to collapse till the very standstill.) Devices constructed on the same principle, such as gyroscopes, are widely used in automatic-control systems for space vehicles. For instance, they help to "store" the spaceship position and maintain it by cutting in and off appropriate engines. The spinning spaceship may well be compared to a massive top. Its spin axis practically does not change its position in space for some time.

If the sunbeams are perpendicular to the surface of the solar-cell panel, the latter produces maximum electric current. Hence, when the storage battery is recharged, the solar panel should "face" the Sun. To attain the required position, the spaceship is rotated. At first, by turning the spaceship the pilot tries to locate the Sun. When the Sun appears at the cross-wire of a special device, it means that the spaceship has been properly orientated. Now, the

microengines are ignited and the spaceship is rotated about the spaceship-Sun axis.

Spaceship control. The position of the spaceship in space is maintained not only by spin stabilization. Performing other operation and manoeuvres, the spaceship is stabilized by the thrust of the engines of the attitude control system. It is done in the following way: at first, the cosmonauts, by firing the required microengines, make the spaceship acquire a given position. On completion of the orientation, the control system is engaged with gyroscopes that have been previously spinned up. They store the spaceship position in their "memory". As long as the spaceship remains in a given position, the gyroscopes are "silent", i. e. they do not produce any signals to the orientation engines. However, each time the spaceship turns, its body is moved in respect to the spin axes of the gyroscopes. This is accompanied by the appropriate commands given to the microengines by the gyroscopes, the thrust of the microengines returning the spaceship to its initial position.

It is possible to stabilize the spaceship without the use of gyroscopes. This is done by igniting the engines manually. But, before "steering the wheel" the cosmonaut must know exactly where the spaceship is at the moment. When we are driving a car we take our bearings using various immovable objects. In outer space, the cosmonauts do the same by watching the nearest celestial bodies and far-away stars.

The navigator of Soyuz has the navigational globe before him all the time. This is the "Earth" that is never covered with the blanket of clouds, unlike the real planet. It is not merely a spatial copy of the Earth's sphere. During the flight the two electric motors rotate the globe round its two axes at a time, one of the axes being parallel to Earth's rotation axis, while the other being perpendic-

ular to the plane of the spaceship orbit. The first movement serves as a model of the diurnal Earth's rotation, while the second movement patterns the flight of the spaceship itself. On a fixed glass, covering the globe, there is a small cross. This is our spaceship. At any time, the cosmonaut, looking at the globe surface under the cross, sees over what part of the Earth he is at present. The sextant, a well known navigational instrument, is also found to be useful for this purpose. The space sextant is not exactly the same as its marine counterpart. The pilot can use it in the cabin, without going out on "deck".

One of the authors of this book took part in space missions as a flight engineer. His personal experience is reflected in the pages that follow.

Soon after entering orbit, we started preparing for our first manoeuvre. It was necessary to transfer our spaceship into the so-called assembly orbit, where right in front and above us Soyuz 5 is making its flight.

From one of the windows we see the Earth. By shifting the handle to the right, Viktor Gorbatko turns the spaceship till the Earth becomes visible in the sighting device. When the handle is shifted to one side the electrical signal is sent into a logical device, which selects the engines to be ignited. The appropriate valves open and the fuel is injected. The spaceship makes a slow turning. In the sighting device we see the contours of the Earth gradually covering the whole scope of vision.

Now it is necessary to turn the spaceship so that the correcting engine could have its nozzle faced in the direction opposite to the vehicle movement. With the engine working in this configuration, the spaceship speeds up and as a result gets into a higher orbit.

Now commander is performing this operation. His attention is wholly centred on the sighting device. In it, the Earth's relief is clearly visible. Details of the Earth's surface are "running" under us. The Earth's "run" has to be vertically orientated. Only then the spaceship will acquire the position we need. Here it is. We fix it by means of gyroscopes. Now it is they,

as was with the control handle some time before, that govern the spaceship. They respond to the minutest deviation of the spaceship from the acquired position, and by sending commands to the engines, they bring it back to its initial position.

Now comes the predicted moment for the ignition of the correcting engine. Instantly we feel a push. The time of the engine work has been preset. After operating for a prescribed number of seconds, the engine shuts off. The trajectory correction is completed, and we are in a new orbit.

Neither hot nor cold. Circling the Earth, the spaceship either plunges into hot blinding sunbeams, or finds itself again in the cold darkness of the cosmic night. The cosmonauts, however, work in light garments, and feel neither the heat nor the cold. The comfortable temperature is constantly maintained in the cabin, which is quite essential to both the people and the instruments.

Before the flight, the spaceship is covered with a shield-vacuum insulation, which consists of a large number of alternating thin metallized-film shields in-between which there occurs vacuum during the flight. It is a reliable protective means against the sunbeams. Gaps between the shields are filled with glass cloth or other materials of low thermal conductivity.

All parts of the spaceship that, for various reasons, are not covered with shield-vacuum insulation, are coated with materials capable of reflecting back into space the greater part of radiant energy. For instance, surfaces coated with magnesium oxide absorb only a quarter of the heat to which they are exposed.

However, by using the passive means of protection, it is hardly possible to keep the spaceship from overheating. That is why more active means of thermoregulation are used for spacecraft.

On the inner walls of the pressure-tight compartments there is a whole maze of pipes. Each of them carries a heat-transfer fluid. On the outside, the spaceship has a

radiator-cooler, the surface of which is not covered with shield-vacuum insulation. Pipes of the active system of thermoregulation are connected with it. The heat-transfer fluid heated inside the compartment is pumped into the radiator which "rejects", radiates the redundant heat into outer space. Further, the cooled fluid returns into the spaceship to resume the cycle from the very beginning.

The heat-transfer fluid can change its course. If the temperature within the spaceship is to be lowered, then its greater part goes to the radiator-cooler, while the smaller part circulates inside the spaceship. If the temperature is to be raised, then the quantity of the fluid on its way to the radiator-cooler is diminished. The distribution is performed by the automatic regulator, to maintain the given temperature in the spaceship's compartments. Cosmonauts can regulate the temperature at their will.

But the thermoregulating system does not only carry away the heat, thus cooling the equipment, spaceship, and indoor air. One of its functions consists in heating the engines and tanks containing oxidizer and fuel. For this purpose it is possible to make use of the Sun-oriented panel heaters through which the heat-transfer fluid is pumped.

Hot air is lighter than cool air. Upon heating, it goes up and pushes down the cold and heavier layers of cool air, bringing about a natural mixing of air, or convection. This phenomenon can be illustrated by the fact that the thermometer always shows exactly the same temperature irrespective of where it is placed in our room.

Under weightlessness, this kind of mixing is ruled out. Hence, in order that heat could be uniformly distributed in the cabin, the air has to be mixed with the help of ordinary ventilators.

In space as on the Earth. We do not think of air when we are on Earth. We just breathe. In outer space, how-

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ever, breathing becomes a problem. The spacecraft is surrounded with vacuum, or void. To cope with the problem of breathing the cosmonauts have to take supplies of air with them into space.

Each of us consumes about 800 grammes of oxygen a day. In the spaceship, air can be stored in special bottles in a gaseous state under great pressure or in a liquid state. However, one kilogramme of this kind of liquid "carries along" with it into space two kilogrammes of metal, of which the oxygen bottles are made, and one kilogramme of compressed gas has about 4 kilogrammes of metal attached to it.

However, we can do without the bottles. In this case it is not the pure oxygen that is stored into the spaceship but a chemical substance containing it in a bound state. A large amount of oxygen is contained in oxides and salts of some alkaline metals, and in the commonly used hydroperoxide. Moreover, oxides have one more advantage. Concurrently with liberating oxygen, they purify the cabin atmosphere, absorbing the gases harmful for man.

Human organism intakes oxygen exhaling carbon dioxide, carbon monoxide, water vapour and many other substances. When carbon monoxide and carbon dioxide are accumulated in the enclosed space of the compartments, they can become poisonous to the cosmonauts. The cabin air is all the time passed through the vessels containing oxides of alkaline metals, or regenerators. In the process, a chemical reaction occurs bringing about the evolution of oxygen and the absorption of poisonous impurities. For instance, one kilogramme of lithium superoxide contains 610 grammes of oxygen and can absorb 560 grammes of carbon dioxide. Potassium superoxide is also widely used.

From time to time we check the composition of atmosphere in our cabin. For this purpose a special instrument called gas analyzer is installed on board. When we switch it on, we look at

the indicator, and see how much oxygen, carbon dioxide, and water vapour the air contains.

Now the display on the panel shows a quiet green light. This means that the ventilator is on and the cabin air is being forced through the regenerator. We may go on with the mission programme. If the evolution of oxygen becomes insufficient or, on the contrary, excessive, and if there is a build-up of carbon dioxide in the cabin, the gas analyzer will show it by a red light on the display. It is hardly possible to overlook it, but, if for some reason we fail to see it, then a loud signal will warn us of the danger.

Setting out to space, the cosmonauts take along, besides oxygen, water and food. Water is kept in special polyethylene bags. In order that it should not loose its freshness and taste, a very small quantity of the so-called conservants are added into it. Thus, for instance, 1 milligramme of ionic silver, dissolved in 10 litres of water, makes the water drinkable throughout half a year.

The water tank has two pipes, one of which ends in a mouthpiece with a self-closing device, while the second is connected with a pump. The cosmonaut uses the pump to produce an excess pressure in the water tank, then takes the mouthpiece into his mouth, presses the button on the closing device and sucks in water. It is the only way one can drink in outer space. In weightlessness, water escapes from open vessels and, acquiring the form of small balls, floats in the cabin.

Instead of paste-like food from squeeze tubes with which the very first cosmonauts were provided, the Soyuz crewmen enjoy practically the same meal we have on Earth. The Soyuz spacecraft even has a tiny "space kitchen" where the ready-to-serve lunch can be warmed.

In many pictures the cosmonauts are shown wearing space suits. They smile at us through the visors of their pressure helmets. The space suit protects the cosmonaut in case the spaceship becomes depressurized.

A space suit

If the pressure in the cabin drops, the automatic device will connect the space suits with air bottles. The space suit is also necessary when the cosmonaut walks in space or on the surface of some celestial body.

The space suit is often compared to a pressurized capsule reduced to the size of a single person. This is quite true. It is not a single piece, but several suits one coming over another. The outer clothing of white colour is heat-resistant and reflects well thermal rays. What comes next

is a suit made of the shield-vacuum thermoinsulation, which followed, in its turn, by a multilayer lining. All this makes the space suit completely pressure-tight.

One of the space-suit linings is ventilatory. Those even remotely familiar with rubber gloves and boots know how uncomfortable an air-tight suit can be. However, the cosmonauts have no such problems. The system of space-suit ventilation relieved them of any inconvenience of this kind. Gloves, boots, and helmet make the cosmonaut's "attire" complete. Now, he is quite ready to go out into outer space. The helmet's visor is provided with a dark-colour screen protecting the eyes from the blinding sunlight.

On the back the cosmonaut carries a pack. In it there is oxygen sufficient to breathe several hours, and a system of air cleaning. The backpack is connected with the space suit through the elastic piping ("umbilical"). The communication wiring and safety tether connect the cosmonaut with the spaceship. What helps the cosmonaut "to float" in space is an individual propulsion unit, a small jet engine, looking like a pistol. Such gas engines were used by the American astronauts in their space walks.

The Earth is always with you. The control facilities for space flights look particularly weird at night. Against the background of the starred sky the uncanny parts of the huge antennas take the form of black shadows. With the bowls of the reflectors turned skywards they look into the boundless space above. Though it is late in the night, the windows are brightly lit. The working hours here have nothing to do with either sunrise or sunset. They are wholly conditioned by the flight schedule.

A starlet appears in the sky. It moves slowly amidst the stars that are immovable. It is the object of observation of a many-tonned bowl of the receiving antenna.

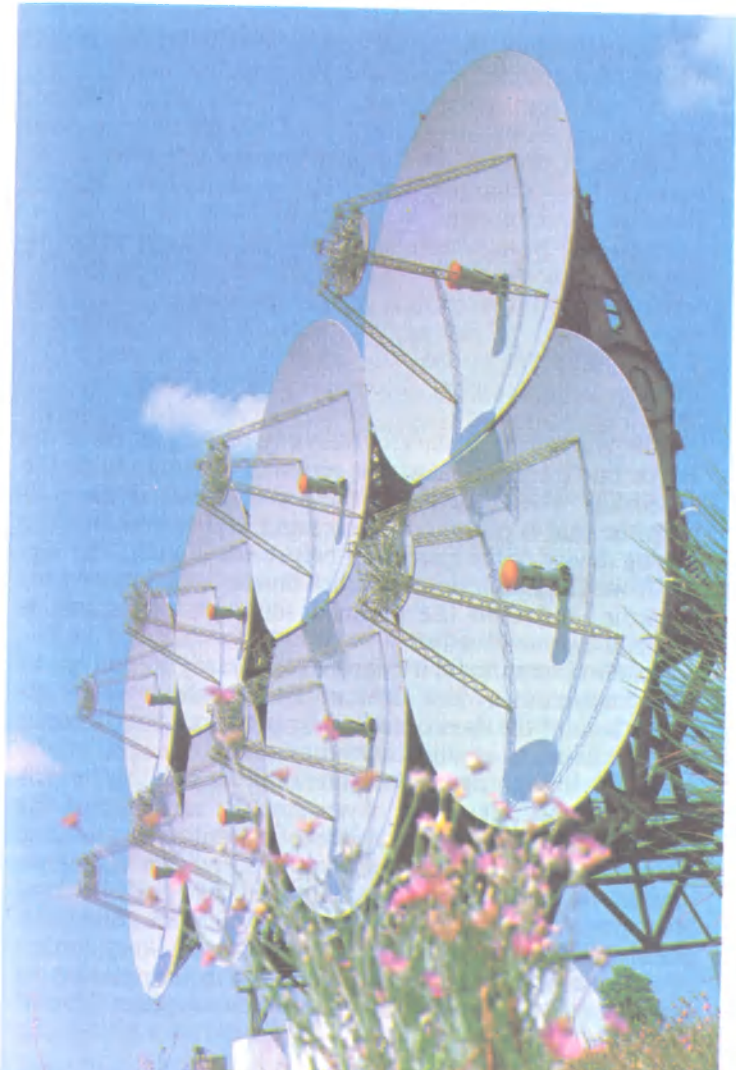
The transmitting antenna is installed at a distance of several kilometres from here. This is the distance at which the transmitters do not hamper the reception of signals from space.

Radio waves, a well-tried and faithful friend of all the modern travellers, serve as a most reliable "go-between", connecting the spaceship with the Earth. All over the vast territory of the Soviet Union, at considerable distances from one another, stations of the telemetry-monitoring complex are set up. Without their constant aid it would be impossible to go on with space missions.

A question may well be raised: why so many space-communication stations are called for? The fact is that each station can maintain communication with a spaceship only for a short period of time (not more than several minutes). After that the spaceship leaves the acquisition range of a particular station. The time is too short to send or receive any adequate amount of information, which, as is known, is always substantial between the spaceship and the Mission Control Centre (MCC). From the spaceship the radio waves transmit not only the reports of the cosmonauts concerning the mission progress, the state of their health and all that seems to be interesting from space, but also a very large amount of telemetered data.

The spaceship is provided with hundreds of sensors. They are placed wherever it is necessary to systematically register the temperature and pressure, velocity and acceleration, stress and vibration in different parts of the structure, etc. Hundreds of parameters characterizing the condition of the on-board systems are measured all the time. The sensors are transforming physical values into electric signals. Thousands of figures per second are

Antennas of the distant-space communication centre



transmitted from the spaceship to the MCC by radio. Many of them can decide the outcome of the mission.

Another question may well arise: why is the telemetered information necessary? Isn't it sufficient for the cosmonauts and on-board instruments to control the work of the spaceship systems? However, if all the parameters we are interested in were displayed on the panel, the spaceship would become extremely complex and much too large. Besides, there are some parameters registered during the flight that present interest only to those who are directly concerned with space engineering.

Every single minute of contact with the spaceship must be used with maximum efficiency. Special instruments installed on board the spaceship help save the time. For instance, the *timing device* receives only one signal from the Earth but transmits a whole series of commands to the spaceship. The sequence of these commands is the programme that is prepared beforehand and stored into the timing device of the spaceship before the launch. The signal from the Earth only switches on the appropriate programme, and then the planned sequence of actions is realized automatically.

Besides commands, it becomes necessary to convey to the cosmonauts orders, advice of the control group, inform them of the data obtained by processing the telemetered information, and introduce some changes in the mission programme. 5-10 minutes cannot possibly be sufficient for all this. That is why on the territory of the USSR we have a whole range of monitoring stations. They are situated in those parts over which the space routes lie. The acquisition ranges of neighbouring stations partially overlap. Without leaving one zone completely, the spaceship finds itself in another. Every station of the telemetry-monitoring complex, on terminating its "talk" with the spaceship, passes it on to another. The in-

Cosmonaut Yuri Gagarin, the flagship of the Soviet space-oriented fleet

formation from space thus obtained is immediately transmitted to the MCC.

The space relay continues outside this country too. Long before the spaceship is launched into space specially equipped ocean-going vessels of the expedition fleet of the USSR Academy of Sciences are put out to sea. One of the ships of this unusual squadron is the motor vessel *Cosmonaut Vladimir Komarov*. Huge brightly shining spheres lend the enormous ship an extra grandeur. The spheres contain the parabolic bowls of aerials. Spherical coverings serve to protect them from strong winds and bad weather, but allows the radio waves to penetrate undistorted. Stabilizing devices and special computers maintain the bases of the aerials in a horizontal position notwithstanding any pitching or rolling. The communication between the vessel at sea and the spaceship in orbit cannot be interrupted even for a fraction of a second.

Numerous laboratories of the vessel are equipped with the most up-to-date instrumentation and computer facilities.

In the Indian, Pacific, and Atlantic Oceans many other ships of the Soviet space-oriented fleet with *Cosmonaut Yuri Gagarin* as their flagship, are on watch.

Here on the Earth we do not only hear the inhabitants of the spaceships, but we can also see them thanks to the television transmitter set up in the crew compartment. The cosmonauts make use of the portable TV cameras to telecast from their space home, and show the televiewers the Earth and the Moon.

Radio ensures a two-way communication with the spaceship. Radio signals sent to Earth from space vehicles are much weaker as compared with those emitted by the powerful radio stations on the Earth. This is mainly the reason why the ground-based receiving antennas are so big. The greater is the diameter of the parabolic bowl, the more energy it will collect from space.

In addition to transmitters on board the space stations and satellites, there are quite a few other sources of radio waves in space. The Earth is bombarded by the invisible rays of the so-called radio stars. The Sun is also a powerful generator of radio waves. In order that the signals from the space vehicle could penetrate through this galactic radio noise, they should be intensified considerably. The systems of complex filters could help to single out the required signal.

The information from space reaches the Earth in a coded form. Radio signals recorded on large magnetic-tape reels call for a most elaborate decoding and an accurate translation into the language clear to the specialists. Moreover, it has to be done within a very short period of time.

The Mission Control Centre is equipped with the most up-to-date computer art (versatile computers perform up

to one million operations a second) and copes with the most complicated calculations.

At the MCC data are processed for orbital corrections, programmes are being worked out for certain circuits, days and communication sessions. At the end of the mission the ignition time of the braking engine is determined as well as the duration of its operation for the spaceship to return to Earth.

Numerous computers of the MCC are at work processing a large amount of telemetry information. The data that come first are those that are relevant at each particular instant of the flight. They are followed by those containing less urgent information. As a result of an elaborate analysis of the information received from the spaceship, the MCC issues recommendations concerning the flight control. That is why the work at the MCC does not stop even when the spaceship leaves the acquisition range for a considerable period of time, or when the crew take a rest.

The mission programme has been fulfilled completely. Now comes one of the most important stages of the space travel – the return to the Earth.

We are getting ready for the landing. Soyuz 24 has left the Salyut 5 station and is circling our planet on its own. To set it on its flight back to the Earth, it is necessary to diminish the orbital velocity of the spaceship, to make it less than the orbital velocity.

For this purpose it becomes necessary to orientate the spaceship for retardation. We watch Earth's surface through the sighting device, and slowly turn the spaceship. It takes some time for the command from the control handle to reach the engines. It is first taken up by the gyroscopes, and then passed on to the logical blocks, determining the duration of work for the engines and the sequence of their ignition. Only after that the command is given to the valves which feed the fuel to the engines.

I press the key on the panel and there appears the green light signalling that the gyroscopes are ready for work. I give the next command, and the display flashes: MANUAL ORIENTATION. Now, when the control handle is shifted, the signal will be directed to the gyroscopes and then to the engines. The orientation engines on board Soyuz are different. Some of them are of lower and others are of higher thrust. The new command is given and the panel flashes: ORIENTATION ENGINES. This means that the low-thrust engines have been selected.

The commander shifts the control handle and the panel starts to flash, which is a sign that the orientation engines cut in and off at regular intervals, and the spaceship changes its position. The Earth's "run" in the sighting device changes its direction, approaching the one that is required. In order to brake the spaceship, the nozzle of its correcting-and-braking engine should face onward in the flight direction. It is important for the Earth to "run" in the sighting device not from top to bottom, as in the case of speed-up, but the other way round.

The panel does not flash any more. The orientation engines are cut off, and now the spaceship rotates by inertia alone. The commander sets the handle to its initial position, the panel starts to flash again, the engines resume their work, now lessening the angular velocity. The spaceship's rotation is being retarded and will soon stop altogether. The required position has been achieved. We can fire the main engine for braking. This will be done exactly at a given time, so that the spaceship could touch down at a place selected beforehand.

After braking, the spaceship separates into modules. The instrument-assembly and the orbital modules become useless and soon burn up in the atmosphere. The re-entry module, with the cosmonauts on board, is moving down towards the Earth.

The outer form of the Soyuz re-entry module looks like a big automobile headlight. This calls for at least a brief comment. Re-entry capsules of the early Soviet spacecraft had the shape of a sphere. After braking and separating into modules, the capsule with cosmonauts on

board made a non-controlled flight down to the Earth along the so-called ballistic trajectory, which, in denser layers of the atmosphere, was always accompanied by large overloadings that the cosmonauts had to experience.

To decrease the G-load during the descent, spacecraft designers made ample use of the experience gained by aviators. When the plane is in the landing approach, the pilot changes the wing lift by extending the flaps and using other contrivances, thus either increasing or decreasing the angle of attack. The latter is the angle between the X-axis (longitudinal) of the plane and the flight direction, while for spacecraft it is the angle between the X-axis of the craft and the oncoming gas flow. In other words, over the landing strip the aerodynamic quality of the flying vehicle undergoes certain changes. (By the aerodynamic quality we mean the relationship between the lift force and the drag.)

During the flight in the atmosphere, the shape of the Soyuz re-entry vehicle also provides the vehicle with a lift force. Its value and direction can be controlled by turning the vehicle round the X-axis with the help of low-thrust engines installed on the body of the vehicle. Thus, the descent using aerodynamic quality is already a descent that lends itself to control.

Manoeuvring along the altitude and the flight direction, it becomes possible to diminish the G-load acting upon the crew twice or three times as compared with the ballistic descent. Besides, the controlled descent makes it possible to enhance the accuracy of touch-down. By increasing the lift force we prolong the descent trajectory, and, conversely, by decreasing it, we make it shorter. Thus, the descent can be achieved with the utmost accuracy as far as the exact landing place is concerned, i. e. where the ground search party is expecting the cosmonauts.

However, G-load is not the only danger that awaits the cosmonauts on their return to the Earth. The other hazard is a very high temperature. The firing of the braking engine enables the spaceship only to leave the near-earth orbit. The main braking occurs at the expense of the resistance due to atmosphere. During the descent there appears a shockwave in front of the vehicle. In it the temperature of streaming air flow reaches 3,500-4,000 °C! It should be mentioned that the temperature at the surface of the Sun is 6,000 °C.

We could considerably reduce the heating by smoothly decellerating the vehicle along the whole descent path using the same engine. This, however, would require a great deal of fuel. Cosmonauts, who think of re-entering by means of engines alone, would have to take an additional amount of fuel, which would be no less than half the weight of their spaceship. Spacecraft engineers, who know how valuable every single kilogramme of payload is in space, could hardly imagine it.

The landing using aerodynamic quality considerably diminishes the heating of the re-entry module. During the controlled descent the surface of the vehicle is exposed to ten times less heat than during the ballistic descent. This is found to be sufficient, though, to melt the metal walls behind which the cosmonauts live and work. That is why the engineers have constructed a heat shield, which is installed on the front, more heated part of the module.

The shield consists of one or several layers of the materials of low thermal conductivity. Under the action of the heat flow, the outer surface of the shield is heated and then, evading the melting stage, turns into vapour. A powerful on-coming air stream disperses the particles of the burning matter, and during the re-entry the heat shield mass diminishes to a great extent. The structure of the vehicle, however, remains unimpaired. The flames raging outside the re-entry vehicle, though in the imme-

diate proximity of the window glass, cannot raise the inside temperature by more than 10 or 20 °C.

Now the velocity of the vehicle decreases to 200 m/sec. The Earth is at a distance of 9 kilometres, and the parachute system can start operating. The hatch door is jettisoned, and a small braking parachute opens to reduce the descent velocity. Another snap of explosion, and the formless cloth of the braking parachute falls off. Above the re-entry vehicle the pilot parachute opens first, followed by a huge multicolour canopy of the main parachute. One more quiet explosion, and, tumbling in the air, the jettisoned bowl of the heat shield is coming down. The mass of the vehicle becomes smaller, which means that the descent velocity decreases too.

The capsule with the cosmonauts on board is making its slow descent. The Earth is only at a distance of one metre. Another explosion follows. Powerful jets of fire shoot from the bottom of the vehicle. The soft-landing powder rockets have been fired. Clouds of dust cover the capsule. A soft tremor, reminiscent of the one we feel in a stopping lift. The flight is over. The spaceship has touched down.

How, then, do spacecraft return to the Earth from planetary missions? The vehicle re-enters the Earth's atmosphere at a terrific speed. It is one and a half times greater than that of the spaceship coming down the near-earth orbit. Lest the G-load during the descent should exceed the limit and the vehicle land at a given area, it is necessary to control the angle and the place of re-entry into the atmosphere.

The landing accuracy is determined primarily by the conditional perigee, i. e. the smallest distance from the Earth, at which the ship would travel if the Earth had no atmosphere. If the conditional perigee is higher than estimated, the space vehicle would experience less intensive retardation in the upper rarefied layers of the atmosphere

and would miss the calculated place of landing. When, however, the conditional perigee is lower than estimated, then an undershot may well be expected. An error in determining the altitude of the conditional perigee within not more than one kilometre leads to a 50-kilometre miss. If the conditional perigee deviates by 10-20 kilometres from the estimated figure, the vehicle can miss the Earth altogether, or the G-load can exceed the limits. In exactly the same way the flight of the space vehicle is affected by the errors in determining the re-entry angle. The interplanetary vehicle is supposed to enter the atmosphere at a very small angle, almost tangentially. A deviation equal to 1 degree from the estimated re-entry angle leads to grave consequences.

When we compare the figures adduced above with the enormous lengths of interplanetary voyages, it becomes possible to appreciate the technical perfection attained by the systems of orientation and control of deep-space vehicles.

As far as the profile of the controlled descent of an interplanetary vehicle is concerned, special mention should be made of a number of points. This kind of descent is far more complicated than the ballistic one, since the vehicle enters the atmosphere twice. When the first plunge into the atmosphere takes place, there is a partial retardation of the vehicle. The control, here, is conducted so that the lift force should not allow the vehicle to go down below the estimated height and be driven out back into outer space. Leaving the denser layers of the atmosphere, the vehicle makes an uncontrolled flight along the ballistic trajectory. Before the second plunge into the atmosphere, the control system again turns and stabilizes the vehicle in a position necessary for the further flight. The descent that follows is practically the same as the controlled descent of an orbital station, Earth's satellite. The controlled descent with a double plunge into the atmosphere

was the final stage in the missions of the Soviet probes Zond 6 and Zond 7, that circled the Moon, as well as the American spacecraft Apollo.

From orbital stations to "habitations in ether". "Mankind will not remain on the Earth forever. In its pursuit of more light and space, it will penetrate, timidly at first, beyond the boundaries of the atmosphere, and then will conquer all the space near the Sun". It is doubtful whether anyone had taken these words seriously as far back as in 1911. But Konstantin E. Tsiolkovsky continued to develop his ideas. 15 years later his plan of space conquest by man appeared. A little over half a century later, half of what he had planned has already been fulfilled.

All in all the plan includes 16 items. This is what the sixth one says: "Jet devices are getting more and more remote from the air envelope of the Earth and remain in ether for greater periods of time. However, they all come back because they have only a limited supply of food and oxygen". What Tsiolkovsky meant by "jet devices" is understood today as space vehicles.

There follow several more stages, some of which have also been covered by now. The tenth item of the plan reads as follows: "Round the Earth we have densely populated habitations". Can you imagine it? 1926! The country had not yet recovered from the two wars: World War I and the civil war. A provincial town of Kaluga... and the words like these. But what seemed to be only a vision in those days, has acquired the features of something quite tangible today! Dr. K. P. Feoktistov, Soviet pilot-cosmonaut, writes: "The project of a space habitation seems quite realistic. There is every reason to believe that in this kind of city it is possible to maintain energy balance in a closed ecological cycle. Conditions for living are not only possible, but highly attractive.

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When people penetrate into outer space, they will not stop at the threshold. They will certainly start getting used to circumstances, settling down in new worlds."

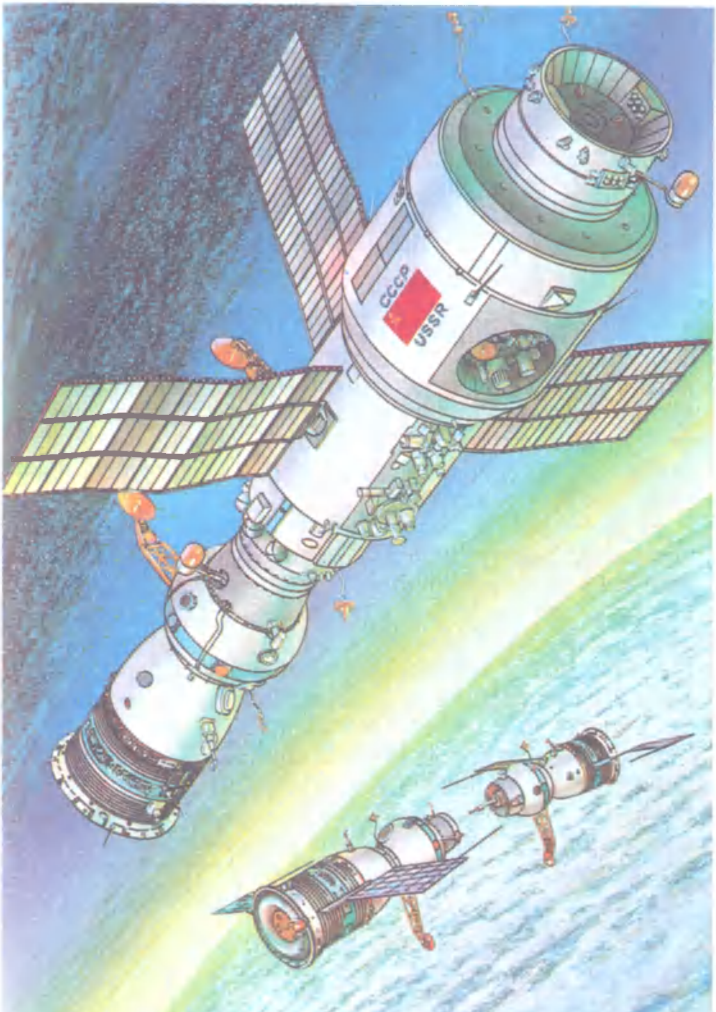
Well, this is certainly not going to happen in the immediate future. To attain the goal we should gradually increase the number of spacemen, prolong their stay in space, and widen the scope of both science and production activity. The first steps along this path have already been made. Orbital stations, quite a new product of space engineering, have actually started operating.

They are heavy artificial Earth's satellites on which cosmonauts can live and work within a long period of time. As distinct from spaceships, artificial satellites do not return to Earth; from time to time they only accommodate new dwellers.

Docking in space. It was impossible to build the stations without having mastered various ways of manoeuvring and docking in space. In 1967 the first automated docking of artificial Earth's satellites was performed by the Soviet Union. In 1969 the docking of the Soyuz spaceships in orbit led to the establishment of a first experimental space station. The docking was followed by a transfer from one spaceship into the other, when the cosmonauts walked in space.

On the 19th of April 1971 the radio announced that the Salyut orbital scientific station was in flight. Soon it received the Soyuz 11 crew including G. Dobrovolsky, V. Volkov, and V. Patsayev. The station became manned. Its dimensions are really fascinating: its length together with the transport vehicle is 23 metres, it weighs

Docked orbital flight of the Salyut-Soyuz complex and the approach for docking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about 25 tonnes, and the volume of the pressurized modules is 100 cubic metres.

From the spaceship the cosmonauts got into the cylindrical transfer module, which contained some of the scientific equipment, as well as the control console of the "Orion" telescope. Then one got into the main part of the space home, or the working compartment. This is the largest part of the station and consists of two cylinders, connected by a cone. The diameter of one of the cylinders is approximately 3 metres, and that of the other is over 4 metres.

In the smaller cylinder there are working places for the cosmonauts and the central control panel. In the conical part of the working compartment there are some facilities for physical exercises, a "stadium" for the cosmonauts, as well as instruments for medical investigations and check-out. Along the running path the crewmen took their "walks" and "runs".

In the working compartment sleeping accommodations were also provided. Sleeping-bags were fastened with belts in a position most convenient for the sleepers. Here too one could find a fridge, water tank, food container, and a kind of stove to warm up lunches. Behind the bulkhead of the working compartment there was a correcting engine which made it possible for the station to manoeuvre in orbit. Orbital stations perform their flights at comparatively low altitudes. As high as 300-500 kilometres above the Earth's surface one can still feel the resistance due to atmosphere. That is why it becomes necessary to correct the orbit and raise its altitude.

A fairly large amount of electrical power is required to keep the systems of the station and the scientific equipment in working condition.

The Salyut crew carried out research on a notably wide scale. On board they had the gamma-ray telescope, the "Orion" complex to investigate the spectra of far-away

stars. It was the first time that such an astronomical observatory had worked beyond the boundaries of the Earth's atmosphere. Devoting much of their time to astronomy, the cosmonauts did not forget the Earth. They closely followed the development of cyclones, studied the snow cover and the state of agricultural lands, determined the purity of air and waters, carried out geological survey to facilitate the exploration of mineral resources, conducted a large number of other experiments in the interests of various branches of national economy. The cosmonauts were also concerned with ... biology, science that seems to be quite remote from their specialized skills.

Even from this short and by no means complete inventory it becomes clear that the crew of the first orbital station Salyut had a wide scope of scientific interests. Their mission lasted three weeks. The cosmonauts had fully coped with the in-flight research programme. The heroic deed of G. Dobrovolsky, V. Volkov, and V. Patsayev was duly appreciated all over the world. V. Shatalov, pilot-cosmonaut of the USSR, said, "We, Soviet cosmonauts, are aware that the road to outer space is not known, it is hard and complicated. But nothing can stop further development and perfection of the Soviet space engineering. Nothing can impede our wish to lay bare secrets of the Universe".

In spring 1973 the first American orbital station was launched. Two English words, "sky" and "lab" were merged into one, thus producing the name "Skylab". The "sky laboratory" originated from the third stage of the Saturn V rocket. In its fuel tank both living and working compartments were arranged. The oxidizer tank was transformed into a waste receptacle. The docking structure together with the air-lock chamber attached to the station increased its length to 25 metres.

In orbit, Skylab was supposed to "spread its wings", or

to use a less metaphoric expression, extend the two panels of solar cells. However, one of the panels was torn away during the take-off, and the other did not extend. Besides, the meteor shield was also lost. As a result of this the temperature inside the space home rose sharply. There were doubts whether the astronauts should be sent to the station or not. Nevertheless, on the 26th of May Apollo with Ch. Conrad, P. Weitz, and D. Kerwin on board approached the station.

After the docking was over the astronauts were not in a hurry to leave the spaceship. At first it was necessary to deploy the remaining solar-cell panel, for which purpose they had to walk in space and reach the panel by climbing Skylab from the outside. Another way to reach the panel was to "drive up" to it by Apollo, which the astronauts actually performed.

Paul Weitz, with his space suit on and waist-high out of the hatch, tried to free the panel using a hook and a cutter. The attempt was unsuccessful. Then, above the station, the astronauts opened a heat screen, which had a close semblance to a parasol. The temperature in Skylab dropped, and the astronauts could get down to work.

With the help of the astronomical instruments the astronauts studied the Sun. From orbit it was possible to watch the development of sun-spots and flashes without any disturbances to seeing. Prominences did not escape the astronauts' attention either. As they reported from orbit, it was the greatest and most incredible phenomenon of all those they had been able to watch on the Sun.

As far back as in 1969 the flight-engineer of Soyuz 6 was the first to perform welding of metals in outer space, which was the first technological experiment in orbit. The American astronauts continued to work along these lines, experimenting with an electric furnace installed in Skylab.

The first Skylab crew stayed in orbit for a month. Two

weeks before the landing they finally managed to repair the faulty solar panel and prepared the station for the reception of a new team. The crew that came next worked in outer space for two months.

Meanwhile the Soviet specialists were doing their best to make Salyut more perfect. Various novelties were consistently introduced into each new version of the orbital station. Thus, substantial changes were made in the power supply system of the third and fourth Salyuts.

Previously, the solar-cell panels were fixed onto the station body, and to derive maximum current both the station and the spaceship had to be orientated to the Sun for lengthy periods of time, retaining the required position by rotation. The solar panels of the new Salyuts gained a certain amount of freedom. They were now able to turn in respect to the body, each with the help of its own drive. According to signals emitted by the solar sensors, the panels exposed themselves to the sunlight. Regular solar-oriented manoeuvring ceased to be compulsory; this meant that the stations became more independent and the time for scientific observations was saved because the time-consuming manoeuvring was totally excluded.

The interior parts of the orbital laboratories had also something new to boast of. For instance, aboard Salyut 4 the cosmonauts collected waste into metal bins and threw them away through specially designed air-locks to allow them to burn up in the atmosphere. The water precipitating from the inside air was also made better use of on Salyut 4. Whereas on Salyut 3 it was utilized only for hygienic and sanitary purposes, the crew of Salyut 4 could even drink it – so pure became the water. Thus, certain elements of the turnover of matter were created in the orbital station. Salyut 4 became also the first station to have a veloergometer serving as an effective means for the cosmonauts to do their exercises.

Salyut 4 was on a trajectory that was higher than that of its predecessors, a fact which had substantially increased the time of its stay in orbit without any trajectory corrections. When the station had no crew aboard, it moved in automatic mode. In this case a significant role was attributed to the new system "Cascade" maintaining the required orientation of the station. Experimental system of autonomous navigation had also been employed for the first time aboard Salyut 4. It relieved the cosmonauts of the daily reception of a considerable amount of information from the Earth, thanks to processing the necessary data on the spot.

Let us imagine a situation when two cosmonauts are asking a third one to join them in their space mission.

"Come along! We'll work the three together. You see, there are so many things to do, to say nothing of scientific experiments. We have to check the orbit without ceasing, and keep in mind the time-table of communication sessions with the Earth, turn the radio on and off, and see that the spacecraft is orientated each time anew. ... Well, all this is terribly dull work, you see, but someone has to do it.

"And from now on this someone is going to be you, thus giving us a fair chance to do some really creative work. And it is wishful thinking on your part, if you expect to be in for a spot of space euphoria. No question of browsing and sluicing either, because the food and water supplies are intended for the two of us only. So, don't purse your lips and start working, old boy. There is something else we wanted to say. You will have to work day and night and, what is more, we won't take you back to the Earth with us. There must be someone at the space station all the time, don't you think so?"

If this kind of conversation had actually taken place, it would not have been a problem to surmise a reply to such a "cordial" invitation. But the fact remains that since the

launch of Salyut 4, there has really been a member of the crew performing all these very monotonous functions. There can be no doubt that the reader has already discovered for himself that the cosmonaut in question is not a human being but a robot. However, it by no means diminishes the highly significant role attributed to the robot in orbit.

In the mission documentation the robot was mentioned as the system of autonomous navigation "Delta". As is known, an orbital station is an artificial Earth satellite, and its relationship with our planet determines the character of its movement. Though invisible, the "ties of blood" can hardly be overestimated. Traces of the atmosphere are still perceptible at flight altitudes and brake the vehicle to some extent, thus making it go down bit by bit. The Earth's gravitational field is so complex that the route of the vehicle becomes unpredictably tortuous. As a result of all this the station's orbit seems to be slightly "floating" in space, and only by taking into account these singularities in its behaviour it is possible to determine the station's location every second. The word "second" is not used here metaphorically. Don't forget that a second in outer space is the time during which tens of kilometres are covered.

Earlier, calculations of this kind were made at the Mission Control Centre and then transmitted to the flight crew. The air was crammed with figures and code letters which, at times, did not allow for transmitting important messages. The crewmen of the latest Salyuts were wholly relieved of such boring chores.

The resemblance in appearance of the robot to Man has long ceased to be a token of perfection of robotics. "Delta" does not evoke any associations with its makers. It comprises a number of small metal boxes with multicolour key-boards and displays. Nevertheless, the robot does have "sensory organs", such as a radio altimeter to

measure the flight altitude, star seekers to track stars, speed indicator, and its own "brain" or what is known as a computer.

The cosmonaut "swims up" to the "Delta" console and presses several keys. With a soft chirr the machine produces a narrow paper tape filled with columns of letters and figures. The output data provide the crew with flight information a day in advance including intervals of communication sessions, time of entry into and exit from the Earth's shadow, moment of intersection of the equatorial plane by the orbit, duration of each circuit, and orbital inclination. In two or three minutes the crewmen are well-armed with a most elaborate flight forecast.

But calculating is not the only thing that "Delta" can do. It can also use the calculational results so as to perform control on its own. The robot can independently switch the equipment on and off, it can run the attitude control system as well as the system of stabilization. Previously all this was done according to instructions from the Earth: "Turn in the direction of such and such star, remain in this position for so much time..." etc. The instructions were sent from the Mission Control Centre and the station had only to fulfil them obediently. Now, however, "Delta" stores in its memory a whole star catalogue and programmes of star tracking.

"Delta", with its wide scope of specialized skills, does not keep aloof from unskilled job. Those involved in experimental work know perfectly well how distracting and tiresome are frequent instrument readings. All what the cosmonauts have to do now is to press "Delta" button and the robot will print out the exact time of taking readings or photos. If measurements are made at dark, which is often the case during astrophysical observations, this kind of service proves to be not only convenient for use, but indispensable.

The next station Salyut 5 also differed from the preced-

ing versions. One of such novelties was the system of stabilization. It involved not only jet engines but a kind of a fly-wheel – a ball suspended in the magnetic field. When the station deviated from some position (as was the case when the cosmonaut bounced from the "wall"), the signal from the control system went straight to the electromagnets, that began spinning the ball. The reactive moment produced by it turned the station in the opposite direction so that it regained its original position. Had the station been stabilized only by jet engines, they would have used up all invaluable fuel on the stabilization alone. The engines of Salyut 5 were set to work only after the ball had reached maximum velocity, which led to a marked saving of the fuel.

Two crews aboard the orbital station accomplished more than 300 various research works and experiments. Besides, a great deal of information obtained was sent back to the Earth. Usually it is done by radio or the materials reach the Earth together with the returning cosmonauts. There was one more advantage aboard Salyut 5. The station contained a small recovery vehicle. As the need arose, it was loaded with appropriate materials and instruments and descended to the Earth on its own.

On 29 September 1977 Salyut 6 was put into orbit. This orbital station had become a reliable space base.

Never before had there been two spaceships stationed together at the same "space pier". It was also for the first time that the guests, arrived on a flying visit, returned to the Earth by the hosts' spaceship. The fact that during the flight the cosmonauts not only sent the research materials but also received "by return of post" the data processed at the ground facilities, was quite a new experience as well. One more new and complex task was also accomplished during that mission. Re-docking! A working manoeuvre, which the future builders of extraterrestrial

townships and factories on the planets will have to tackle not infrequently.

Weeks, months and years passed. One crew came in place of another. The station proceeded to operate as reliably as before, providing the cosmonauts with every single opportunity to carry out the planned research item by item. To extend the flight time, make the mission more eventful and fruitful – all this was first achieved in orbit owing to the Soviet cargo spaceship Progress. The longer the station stays in orbit, the less fuel remains in its tanks. For the first time, the refuelling in outer space was handled by Progress, a space-going tanker.

Outwardly Progress looks very much the same as Soyuz. Though it has actually been developed from Soyuz, some changes were necessarily introduced into the new vehicle according to its purpose. First and foremost, it became *unmanned*. Consequently, systems that had been controlled by cosmonauts were of no further use. They were replaced by those executing instructions from the Earth *automatically*. Since there was no crew on board, the re-entry module, with all the systems ensuring the descent and landing, became redundant. What came in their place was a compartment with tanks containing fuel and oxidizer, while the orbital module (where the cosmonauts of Soyuzes are used to spend most of their time) took up the functions of a freight compartment. Progress delivered to the orbital station regenerators of air, filters, absorbers of carbon dioxide, and other necessary units and components. Progress also brought drinking water, food, reserves of air, clean garments and a host of other things, among which there were also "Splav", a test installation for technological experiments, and other research equipment.

The fuel transfer had been preceded by lengthy preparations. There was no previous experience to be guided by. For all that, the refuelling in orbit was accomplished

successfully. After that the cosmonauts carried over all the cargo from spaceship into the station, and put everything in its place. Unnecessary equipment and useless packing were put into Progress and allowed to burn up in the atmosphere.

The first Progress paved the way to ferry spacecraft that came next. Thus, the Earth-orbit route was opened up by one more type of aerospace transport.

During the Salyut 6 mission, an improved version of manned spacecraft – Soyuz T – was tested. It was to succeed the veteran vehicle Soyuz. Having preserved the main outward features, the new spaceship essentially differed from its predecessor. First and foremost, it was the new motion control system, which was the first to incorporate a special computer complex. Automation, reliability and accuracy of control both in the orbital flight and during the re-entry were brought to a higher level, which facilitated the spacemen work to a great extent. Some other vehicle-borne systems were also replaced with more advanced ones. The Soyuz T vehicles were flown to the space station four times, and with each new flight the cosmonauts became ever more convinced of superior performances of the new spacecraft.

The cosmonauts must occasionally leave the station. This is conditioned not only by a prolonged physical confinement and need of exercise, but by purely practical purposes. The crew must necessarily have access not only to the systems and units inside the station but outside it as well. It is only then that the cosmonaut can become a full master of his space home.

The first time the "door" of Salyut 6 opened was one and a half weeks after the first crew arrived to the station. G. Grechko and Yu. Romanenko were expecting the guests. Almost everything had been made ready, though there were still some doubts. Soyuz 25 that had approached the station two months earlier could have

caused some damage to the elements of its second docking unit. It was necessary to see that it was in perfect order, or, in case it wasn't, to repair it immediately. The unit proved to be functioning properly and in twenty days' time it received the spaceship piloted by O. Makarov and V. Janibekov. The "mooring" facilities of Salyut were in perfect working condition.

But extravehicular activity became again necessary. It was time to remove what had been installed on the outside of the station – a device to register micrometeorites, containers with organic substances, optical and constructional materials – and to replace them with new ones, and mount an instrument to register cosmic X-ray radiation. By that time the station had been in orbit for nearly a year, so meteoric bombardment and cosmic radiation must have left their marked traces on the specimens fixed onto the outside part of the station.

The new outfit for cosmonauts. The inhabitants of Soyuz 6 were the first to wear space suits of a new design. They made us think of the medieval knights. The authors of the new space suit had evoked these associations themselves when, in describing the new outfit, they mentioned a cuirass (a piece of armour consisting of two metal plates connected by belts and shaped so as to contour the warrior's breast and back). And now, hundreds of years later, a cuirass has transformed into a metal trunk of the new space suit. It must, however, be mentioned that in outer space the cuirass has got rid of its heavy weight, the deficiency that was the main reason why it went out of vogue sometime in the past.

A list of the operations to be successively followed by the cosmonauts before going for a space walk reads, among other things: "Enter the space suits". No, the space suits are not to be put on, they are actually to be entered. The cosmonauts enter, or swim (if this word

appeals more to the reader) through a hatch at the back as through a door. On the hatch lid there is a backpack of the life-support system. A helmet with a glass visor is firmly fixed onto a hard trunk, with covers for the hands and legs remaining soft as before. The space suit made it possible for the cosmonaut to breathe, created a normal microclimate and helped to perform various working operations in space. The backpack became part and parcel of the space suit, without being connected with it, as before, by outer pipes. The space suit now has fewer fastenings and, as a whole, is more reliable and safe.

Salyut 6 could rightly be called both a flying astrophysical observatory and a factory shop in orbit. It has also served as a testing laboratory for quite a few innovations.

Methods of modern astrophysics are remarkable for the exceptionally high degree of resolution. Radio telescopes make it possible to scrutinize and identify separate molecules in interstellar space. X-ray telescopes tell a story about the atoms constituting these molecules, while gamma-ray astronomy goes even farther, straight into the nucleus. It should be particularly stressed that all this takes place at an incredibly great distances, which are covered by light – which knows no competitors in speed – in hundreds and thousands of years.

But cosmic gamma radiation is impossible to observe from the surface of our planet. In fact, it is entirely absorbed by the Earth's atmosphere. Besides, its wavelength is millions of times shorter than that of visible light, and hence it is not perceived by the eye. The researchers, however, coped with both the problems. Imperfections of the human eye were compensated by special cosmic-ray counters, while the satellites enabled the instruments to be brought beyond the dense atmospheric layers.

The cosmic gamma radiation has much to relate. If there are antiworlds in the Universe, it can testify to their

existence; it also explains the spiral structure of galaxies. By reading messages sent from deep space in the language of gamma rays, it becomes possible to create new models of the Universe and reject old ones.

However, the gamma-ray telescope "Yelena" installed on Salyut 6 did not claim to take upon itself the role of something to shake the cosmic theories. The aim pursued by the designers of the small device was much more modest – to indicate the demands to be imposed on orbital telescopes of the future. It was a problem that "Yelena" managed to solve successfully.

The space-borne radio telescope KPT-10 was first tested on board Salyut 6 as well. The new instrument, even when folded, hardly found enough room in the compartments of the ferry spacecraft that delivered it into orbit. And it was not surprising. The bowl of its antenna was 10 metres in diameter, which could well be compared with the dimensions of the station itself. The mounting of such a large structure in orbit had never been carried out before. Soon the station was adorned with a huge metal "parasol" shining brightly in the Sun.

It has always been a cherished dream of the radio astronomers to have their own observatory in outer space. It is not only that on the Earth their instruments have already reached practically limiting size. The freedom of weightlessness has a fascinating attraction for designers. This is what the journalist Ya. Golovanov writes on the subject, "The architecture of weightlessness is the architecture of boundless dimensions. I don't think that a house twenty-five kilometres tall could ever be built on Earth. In outer space there will be no problem to do this." But what weightlessness also implies is unrestricted mobility, a quality that is by no means of minor significance to radio telescope antennas.

The cosmonauts employed KPT-10 to radio-map the Milky Way, study the solar radio emission, and hear the

pulsar's "voice". Its Earth-oriented antenna made it possible to gather information on the Earth's surface, World Ocean, weather conditions. Besides, the all-seeing radio waves allowed the observations to be conducted day and night, rain or shine.

KPT-10 cannot but bring back into our minds one of the dramatic episodes connected with that flight. It was when the observations were nearing the "final curtain", so to speak, that the telescope gave the crew a nasty shock. The antenna bowl was fixed outside close to the docking unit. To leave the bowl in its place meant depriving the station of one of its two docking interfaces, namely of the one to receive Progress space ferries. That was why it became necessary to separate the antenna and remove it from the station. All that had to take place "in accordance with the programme". When we come across these words we sometimes fail to see the difficulties that lie behind. It will take us a long time to make outer space our home, quite a lot of things will have to be done for the first time, and the environment alien to man will more than once resist the implementation of our plans.

It was exactly the case on that occasion. The huge latticed structure, having removed from the station, did not move straight ahead, as it was supposed to, but made a slight turn and so had one of its edges hooked onto the protruding cross of the docking target. At first the cosmonauts thought it was a mere trifle. But all the manoeuvres of Salyut to rid itself of the unnecessary load turned out to be of no avail. The antenna turned aside even more but was tenaciously holding on the station as before.

Having analysed the situation, the members of the crew made a daring decision to walk in space and try to solve the problem by hand. The ground-to-space television communication line (that had first been tested on Salyut 6) rendered its service transmitting from the Earth

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an elaborated plan to uncouple the antenna. After carefully studying and discussing the plan with the specialists of the Mission Control Centre, the crew managed to cope with the problem that was in no way an easy one.

Salyut 6 accommodated a real materials laboratory equipped with two electric melting furnaces. In the first of them, "Splav", various alloys, semiconductors and optical glasses were produced under weightlessness. At the same time the cosmonauts also made use of the "Kristall" furnace which had a narrower scope. It produced only semiconductors, but could do it in four different ways. The installation comprised a control computer that could conduct automatic heating under several temperature conditions.

The installation for application of metallized coatings on various surfaces was also first tested on board Salyut 6. Such coatings are vital for spacecraft in that they provide appropriate heat conditions, protection against ionizing radiation and so on.

The longer a space vehicle is in flight, the more traces are left on its surface by outer space. Micrometeoric dust, solar short-wave radiation, sharp and frequent variations in temperature, and high vacuum all serve to gradually deteriorate the coatings. Nowadays, when the duration of space missions is associated rather with years than months, the necessity to have the outer coatings repaired becomes more and more pressing.

That was accounted for the urgent need to test the above installation "Isparitel". As had been expected, the process in outer space was quite different from what it was on Earth. As early as during the very first tests, the researchers encountered what had been unforeseen. It seemed that weightlessness would not exercise any marked effect upon the vaporization and condensation of metals, which, in essence, constitute the process of film coating in space. However, among specimens obtained

there were some with quite unusual physical and mechanical properties. Thickest specimens displayed those features more conspicuously. Films that on the Earth lose their smoothness and lustre with an increase in thickness, had mirror-like lustre in space.

The first tests in orbit have given us some reasons to believe that there are new and attractive horizons ahead. It is quite possible that in the future "Isparitel" will acquire the form of a spraying gun and the cosmonauts will, from time to time, use it like a paint sprayer to apply a new coating to their space home. It may also become an automatic installation to be controlled by radio. Time will show. It is quite probable that using similar contrivances it will be possible not only to do repairing works in space but to produce large-size structures. Huge shiny reflectors using the film produced in orbit will "collect" the solar energy and transmit it to the Earth. The light of gigantic space-borne mirrors will prolong the day on the fields, and colossal bowls of radio antennas will detect voices coming from far-away worlds...

The Salyut 6 orbital station became a real space long-liver. During more than four years it had been circling the Earth, circuit by circuit. The station received twenty Soyuz and Soyuz T spaceships with crews on board, twelve Progress space ferries that had been regularly prolonging its life in orbit. Salyut 6 was the home of five basic expeditions, and almost each broke the duration record of manned flight, which, in the long run, amounted to 185 days. All in all the space laboratory was inhabited for nearly two years. Three times the cosmonauts left the air-tight quarters to walk in space. The station was eleven times visited by guests, in nine cases of which it received citizens of the socialist countries.

Salyut 6 terminated its flight in summer 1982. By that time its successor Salyut 7 had been functioning in orbit for a third month already. Its crew was also in for quite a

bit of work that was to be done for the first time.

Thus, during that flight the orbital station had for the first time become a branch of the Baikonur cosmodrome. On one of the days in May 1982 Salyut 7 launched the artificial Earth satellite Iskra 2 designed and produced by the students of the Moscow Aviation Institute.

Iskra 1, made by the students, was put into orbit about three years ago. That was a repeater through which the Soviet and foreign amateur radio operators could communicate. During the first month in flight the satellite rendered its services to amateur radio operators of more than one hundred countries, separated from one another by many thousands of kilometres.

The Salyut 7 crew utilized the nominal air-lock chamber as a launcher. There are two chambers of this kind on board the station. The cosmonauts make use of them for waste disposal or for scientific experiments in outer space. In so doing, the cosmonauts remain in the pressure-tight compartments.

A few words about the design of the air-locks. They consist of two spherical casings, one being firmly attached to the station body, and the other being movable inside the first. The outer casing has two openings, inlet and outlet, through which the air-lock can be connected with the pressurized compartment of the service module and with outer space. The inner casing has only one opening. It serves to load the chamber with waste-disposal containers or scientific equipment. During the loading, the inner casing shuts snugly the outlet with its rear side. On the completion of this operation, the cosmonauts close up the inlet hatch and turn the inner casing so that its opening would coincide with the outlet, and then with the help of spring pushers throw the container outside.

The launch of Iskra 2 was accomplished when Salyut 7 was within the acquisition range of the control station of

the Moscow Aviation Institute. Thrusting itself from the orbiting launching platform, the satellite slowly departed and began its own flight.

With the help of the X-ray telescope mounted on Salyut 7, the cosmonauts detected the radiation of many interesting astronomical objects. The vast territory of our country makes it possible to track the chosen stars and galaxies for a long time, "passing them over" from one ground-based observatory to another as the Earth rotates. A comparative study of such investigations and the spacecraft observations enabled the scientists to obtain what may justly be called unique information on the sources of cosmic radiation.

New items also appeared in the station's technological equipment. A new installation "Korund" was added to the already functioning "Splav" and "Kristall".

The Salyut 6 and Salyut 7 missions differed from the preceding flights in their duration and extensive scientific research. Simultaneously linking-up with two spacecraft of different designations and thus forming hitherto unknown orbital complexes of immense size and possibilities, the space stations of a new generation represent the first specimens of the "architecture of weightlessness" that has never existed before.

Thus, owing to the consistent efforts of scientists and designers, step by step, the perceivable features of the future "ethereal habitations" acquire a clear-cut form.

But the thoughts of those who develop space technology go much farther even today.

It may well be assumed that orbital stations of the future will be assembled in the same way as modern buildings – from prefabricated blocks. Parts of the station could be delivered to a near-Earth orbit and there brought together. Individual living modules must be pressure-tight, so that even hits of large meteoric particles would not make the station inoperative.

In some of the projects, artificial gravitation force is regarded as quite a feasible proposition. The terrestrial gravitation can be replaced by the centrifugal force due to slow rotation of the station. To a great extent, this accounts for the shape of future orbital stations. Various designs are being suggested now, e. g. huge "automobile tyres", "dumb-bells", "wheels", "stars", etc.

To launch manned spacecraft to far-away interplanetary missions, it will be necessary to have intermediate stations in near-earth orbits. There it will be practical to set up jigs for assembling huge interplanetary liners, since to send such a vehicle into space from the Earth will be above the strength of even the most powerful rocket. Large long-lived orbital stations will become actual launching pads in outer space.

A Relay of Cooperation

A little over sixty years ago, when the idea of space flights was considered to be the product of fecund imagination, the great Russian scientist Konstantin Tsiolkovsky published his book *Outside the Earth*. It was a science-fiction novel coming from someone who lived and worked as a teacher in a small provincial town in Russia, and was trying to picture for himself what the first space travel would be like. Quite a few remarkable ideas expounded by Tsiolkovsky in the book have already been implemented, but what is really of paramount significance for us today is the role attributed by him to internationalism. The spaceship construed in the author's mind is inhabited by scientists from all over the world. Each one of them is highly competent in his particular field, and all of them taken together form a friendly crew, or a psychologically compatible alliance. Now the time has come when this dream, too, can hardly be called wishful thinking.

In 1976 the Soviet Union offered the socialist countries to participate in the manned flights aboard the Soviet spaceships and stations, thus developing the joint research and use of outer space for peaceful purposes. The flights were scheduled for the period from 1978 to 1983. In the same year of 1976 the first group of candidates from Czechoslovakia, Poland, and the German Democratic Republic arrived at the Yuri Gagarin Training Centre. It was the beginning of an entirely new stage in joint space efforts of the friendly countries.

Ten socialist countries have long been participating in the Intercosmos programme. They do not only promote its implementation, but make use of the scientific and practical results rendered by it. In order that we may feel the scope of this cooperation, it would suffice to mention only its basic trends.

More than 20 satellites of the Intercosmos series and a dozen of high-altitude rockets of the "Vertical" type were equipped with instrumentation for scientific research designed and produced in Bulgaria, Hungary, the German Democratic Republic, Poland, Rumania, the Soviet Union, and Czechoslovakia. The instruments were set on the Soviet sputniks (artificial Earth satellites) Kosmos, Meteor, space probes Prognoz, spaceships Soyuz. With the help of the Soviet sputniks the socialist countries develop weather forecasting, telecommunications, and television transmissions. Space research has also provided tangible findings in the study of natural resources.

All this convincingly demonstrates the high level of science and technology in the socialist countries. But the acme of achievements in space efforts is still with the manned flights. Within the period from March 1978 to May 1981, citizens of all the nine friendly countries took part in space missions. On board Soyuz and the orbital station Salyut 6 the Soviet cosmonauts worked together with V. Remek of Czechoslovakia, M. Hermaszewski of

Poland, S. Jahn of the German Democratic Republic, G. Ivanov of Bulgaria, B. Farkas of Hungary, Pham Tuan of Vietnam, A. T. Mendez of Cuba, J. Gurragcha of Mongolia, and D. Prunariu of Rumania. Each of these missions lasted a little over a week. The international crews arrived at Salyut 6 to find one of the regular Soviet teams busy at work there, and rolling up their sleeves, the crews tackled extensive programmes of scientific experiments.

Orbital stations are very often called scientific laboratories in space. The definition is by no means inaccurate. But it is difficult to imagine a laboratory with its workers being simultaneously involved in research pertaining to astrophysics, medicine, geology, botany, meteorology, and technology. According to the standards we have here on the Earth, the capacity of the work done by the space laboratories calls for a whole university rather than a single institute. But even at the universities specialists are concerned with their own narrow fields of research. Members of the international crew, however, had to combine various kinds of research involving quite different specialized skills.

The guests of the orbital station devoted most of their time to the study of the Earth, and in particular, the territory of their own countries. Each of them has its own specific geographical, geological, climatic, and other features, which, in the long run, determine the research programme. Thus, for instance, the Soviet-Vietnamese crew was particularly interested in the drifts of the Mekong delta and in the development of powerful cyclones. The crew with the Cuban cosmonaut did much to study the geological structure of Cuba, and in particular the zone of Pinar del Rio. The Hungarian hydrologists received from their fellow-countryman in space new data concerning the Lake of Balaton and the Danube. The geologists in the German Democratic Republic got a bet-

ter understanding of the structure of their country's mountain massifs after the joint USSR-GDR space mission had been completed.

It is self-evident that items of the Earth-oriented programmes assigned to different international crews had quite a few things in common. Thus, every single crew was interested in atmospheric pollutions, complex meteorological phenomena, state of forests and agricultural lands, geological features, etc. All the international crews, for instance, were deeply concerned with searching for the so-called ring structures on their countries' territories.

These unusual formations on the Earth's surface deserve consideration at greater length. Most of them remained unknown before space flights began. Later, the photographs taken in space revealed certain whimsical ovals, arcs, and circles. They were scattered throughout all the continents, occupying, at times, vast areas. It took some time to figure out why they had remained invisible before. The mysterious circles often reach several hundred kilometres in diameter, and things that are large are best seen at a distance.

The ground-based explorations did not shed much light upon this problem. Most often, in those areas where from space wide curved bands became visible, nothing remarkable was found. The uncanny rings could not be associated with any particular phenomenon. Discernible through thick forests and sand dunes of deserts, they "impudently" crossed the water divides and mountain ranges. This means that the ring structures are situated much deeper than the upper layers of the Earth's crust, deformed in the process of mountain formation.

Some scientists think that about five milliard years ago the Earth was like a big moon. From its depths out onto the surface there sprang fire-spitting streams of magma. In the process of solidification they became huge massifs

of basic rocks, round which the zones of high permeability or deep ring fractures were formed. This, presumably, accounts for the fact that these zones are seen even now. As we know, under the Earth's crust the processes of radioactive decay of elements take place until now and they are attended by the enormous heat evolution. Quite naturally, it is much easier for the heat to follow the former break-through of melted masses. If a certain part of the Earth's surface is continually being heated, the soil and vegetation on it will have their own characteristic features as distinguished from the surroundings. Here are visible indications. Note, visible from space.

These hypotheses are confirmed by the facts that are now at our disposal. Thus, for instance, some ring structures were found to be associated with thermal anomalities. There is but one more thing that relates the relict ring structures of the Earth with the lunar seas. Over some of the Earth's ovals an increase in gravitation was noticed. It would not be out of place to mention here the famous mascons, or mass concentrations in the circular lunar seas.

The ring fractures play a particularly important role in the occurrence of rare metals. The ring structures present considerable interest for predicting hidden "blind" deposits of other valuable minerals. It has been noticed that diamond-bearing rocks and phosphorites tend to be near the centres of the ovals, while mica is to be found at their periphery; some of coke coal deposits coincide with the places of contact between various ring structures.

The ring structures yet unknown were discovered on the territory of many socialist countries, which has made it possible for geologists to conduct their exploratory work more purposefully and attain significant finds.

In the course of international Earth-oriented experiments conducted on Salyut 6, the specialists received

about sixty thousand spacecraft-borne photos, as well as spectrogrammes, sketches and entries in the log-books.

The programme of every international mission also included research in the field of materials processing. During the flight of Salyut 6, the electric melting furnaces "Splav" and "Kristall" yielded over 300 samples of various materials. About 50 of them were obtained by using the methods elaborated jointly by the scientists of the socialist countries. The international crews brought to Earth materials that were produced in a state of weightlessness: crystals indispensable for detectors of thermal radiation in astrophysics and medicine, semiconductors for microelectronics (including electron optics), crystals to be used in making lasers, solar cells and thermocouples. The experiments using "Splav" and "Kristall" were supplemented by the Cuban experiments to grow monocrystals of organic compounds in space.

As is known, first days in orbit are usually the most difficult for cosmonauts. They have to get used to weightlessness, their organism must accommodate itself to circumstances, which is connected not only with disturbing sensations, but with a marked reduction in working capacity.

Short and practically successive flights of the international crews offered space medicine a rare opportunity to study properly the period of adaptation to unusual conditions of habitability. Hence, medical research programmes of the joint flights were well adjusted to supplement and improve each other.

The specialists of Czechoslovakia developed a device to investigate the oxygen saturation of tissues. The method and equipment were employed by a number of crews. Polish, Mongolian, and Rumanian specialists in medicine focussed their attention on the activity of the cardiovascular system. The mental capacity was studied by the specialists of the German Democratic Republic,

Bulgaria, and Hungary. In Cuba a special method was worked out for the cosmonauts to study the mobility and the sensitivity of fingers. The use was also made of the Cuban experience in manufacturing foot-wear for sportsmen and for foot disorder cases. The special foot-wear, by exerting pressure on the feet, imitated terrestrial walking and thus restored the functions that had been lost during the flight.

The work of various analyzers of human organism was also given due attention in the international flights. Changes in taste, hearing, and acuity and depth of vision were registered by the crews which included the cosmonauts of Poland, the German Democratic Republic, and Hungary.

Every life form on Earth is subjected to the gravitational force. This is so natural and habitual that we rarely give a thought to the role played by gravitation in the processes of growth and development. But isn't it under the influence of this factor that all exterior forms of plants, animals, and humans were formed? We owe it to gravitation that we see the terrestrial life as it is and not in any other form. It is quite natural that basic biological processes on the Earth must be markedly different from what we could observe in space. However, it is only experiments that can throw light on this problem.

Biological experiments were conducted by practically all flight crews. The international crews on board Salyut 6 were by no means an exception. They directly took part in experiments involving tissue culture produced in the German Democratic Republic, colonies of yeast cells from Cuba, chlorella, cultivated in Czechoslovakia, fern and blue-green algae from Vietnam...

On the 24th of June 1982, Soyuz T-6 with the Soviet-French crew was launched from the Baikonur cosmodrome. In space it was expected by the new Soviet orbital station Salyut 7 with A. Berezovoi and V. Lebedev on

board. Just as his colleagues from the socialist countries, the first cosmonaut from Western Europe Jean L. Chretien spent one week in orbit aboard Salyut. This time, too, the newly arrived devoted much of their attention to medicine. By using the ultrasonic equipment produced in France, they determined characteristics of function of the heart, measured the velocity of blood flow in vessels and their dimensions. The experiment "Poza" studied the interaction of sensory organs and motor system. Another experiment investigated peculiarities in the formation of microflora during the presence of two crews on the station.

The Soviet-French crew did much work in the field of astrophysics. Two special high-sensitive photographic cameras helped the cosmonauts to detect the minutest radiations of the night sky; in particular, the light from deep-space sources that are beyond the confines of our Galaxy. The significance of these photographs is determined by the fact that ground observations like these are impossible because of the atmospheric disturbances.

For their own space mission the French scientists had prepared ampoules containing various metals which, in space, were heated in the electric furnace "Kristall". This was accompanied by studying diffusion of one metal into another under weightlessness. Alloys were produced which were composed of metals, that under normal terrestrial conditions won't mix on account of different density.

The Soviet-French crew carried out biological experiments too. In one of them, reactions of microorganisms to various antibiotics under space flight conditions were investigated. The results of these experiments are likely to help in development of effective medicines for cosmonauts.

Congratulating the crew on their successful return to the Earth the President of France pointed out that as a

result of the space mission an enormous amount of information had been gathered. He particularly stressed its value for the international scientific cooperation, which would lead to further development in medicine, biology, materials science and astronomy. What the President said can be equally referred to the international space missions in the past and those that are yet to come.

Soyuz-Apollo – a Handshake in Orbit

A space crew can at any time find itself in a predicament. To avert disastrous consequences spacemen of different nations should not only be ready to come to the rescue of their colleagues immediately, but also to possess the technical possibilities to do so. It was with the aim of producing means of this kind that the two first space powers have amalgamated their efforts.

The agreement signed by the USSR and the USA in May 1972 read, "The parties have agreed on producing joint means for promoting the rendezvous and docking of Soviet and American manned spaceships and stations, thus enhancing the safety of space flights and providing all the necessary conditions for joint scientific experiments in the future."

Spaceships with a substantial time in service had been chosen for the occasion. The Soyuz spaceships had had a number of rendezvous and dockings, delivering the cosmonauts to the Salyut orbital scientific station. It would hardly be possible to call the American spacecraft Apollo novices in space.

The experience of space rendezvous proved to be helpful to both the Soviet and the American designers. But in order that the independently developed vehicles should form a whole, it was essential that quite a few changes were introduced into their configuration. First and foremost, it concerned their systems of approach and dock-

ing. Using the specialists' idiom, "they had to be made compatible". The expression was very well explained by N. N. Rukavishnikov, pilot-cosmonaut of the USSR. He said, "If the key opens the lock, it means that they both are compatible". Developing this idea, it becomes possible to say that in the key-lock pair the active member is always the key. The lock is only the recipient of the action, and merely expects to be either locked or unlocked. It is exactly the same with the two spaceships during the docking. One of them is always the active member, whereas the other is passive.

It was decided that the docking unit for Soyuz and Apollo should be identical. This enabled either of the two spaceships to dock with the other.

At one of the press-conferences in Moscow, the journalists asked the Technical Director of the Apollo-Soyuz Test Project to say how the new docking units were constructed and how they would act in space. The answer was succinct and required no translation. Dr. Lunney spread his hands and then brought them together so that the fingers of one hand firmly clasped the fingers of the other. Indeed, the new docking units of Soyuz and Apollo looked very much the same as the two palms.

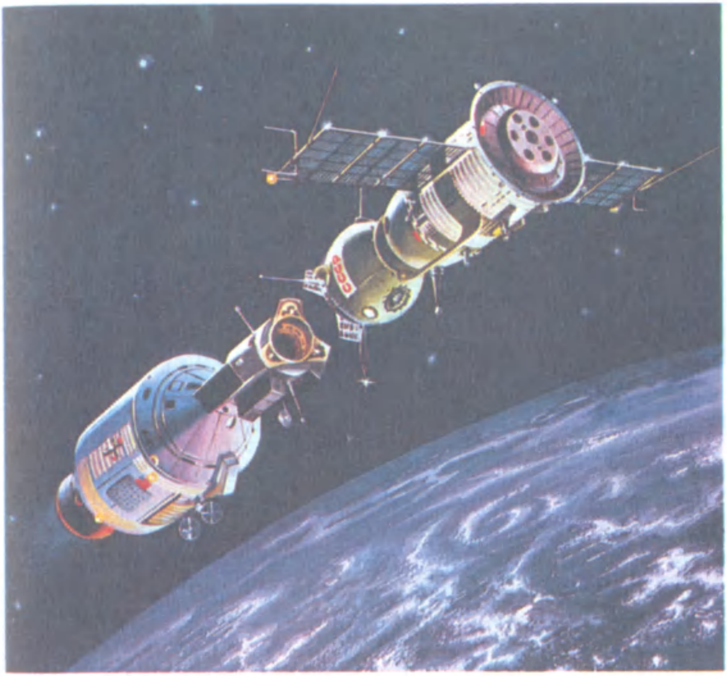
Docking. But can docking alone be sufficient for cosmonauts, or astronauts, to move from one spacecraft into the other? Before giving the answer to this question it would not be out of place to say a few words about divers. Why is it that they emerge from considerable depths very cautiously and slowly? Well, it is because when there is a marked decrease in pressure, the latter being always greater under water than on the surface, the blood begins to release bubbles of nitrogen dissolved in it, and the blood vessels become obstructed by gaseous "plugs". All this causes great pain in the muscles and blood vessels.

It would have been exactly the same with the spacemen when moving from the Soviet into the American spacecraft. The fact is that the atmosphere of Soyuz practically does not differ from the atmosphere that we have here on the Earth. The same pressure and the same composition. The compartments of Apollo are filled with pure oxygen under the pressure which is three times lower.

There would have been no problem if the two spacecraft had had the same atmosphere. But this would amount to introducing substantial alterations in the systems and design of at least one of the spacecraft. Hence, it was decided that Soyuz and Apollo would meet half-way. To avoid the unpleasant consequences resulting from the change in the pressure during joint operations, the pressure in Soyuz was to a certain extent lowered, and in Apollo it was raised. The mixing of the two atmospheres, different in their composition, was averted by means of a specially devised lock chamber, or what is called the *docking module*. The cosmonauts, or the astronauts, on entering the module, had to make sure that the hatches separating them from their home vehicle were firmly closed and create in the lock chamber the atmosphere of the hosting vehicle. After that there was nothing to prevent them from paying their visit.

To achieve perfect mutual understanding, the guests and the hosts should speak a common language. The variant that was chosen was equally good for each of the two parties. The American astronauts had to address their Soviet colleagues in Russian, and receive the answers in English. And though Alexei Leonov and Valeri Kubasov were not particularly good at English pronunciation, and Thomas Stafford, Vance Brand, and Donald Slayton found Russian words difficult, the Soviet cosmonauts and the American astronauts were soon able to understand each other perfectly well.

On the 15th of July 1975 at 3.20 p.m. (Moscow time)



Soyuz and Apollo during their joint mission

the Soviet spaceship Salyut was launched from the Baikonur cosmodrome. Seven and a half hours later the Apollo spacecraft followed it from Cape Canaveral. For 2 days the two vehicles were flying apart from each other. Then they met in orbit.

Let us say a few words about the joint experiments carried out in orbit by the Soviet and American spacemen.

A large number of melted substances, when cooled, are being transformed into a crystalline state. On cooling, the

6–630

A diagrammatic presentation of the Soyuz-Apollo flight

chaotic movement of atoms in the fiery liquid becomes retarded and regular. Each atom gradually finds the place allotted to it and settles down there, forming with myriads of its "fellows" a neat pattern of a crystalline lattice.

The forces under the action of which the process takes place, are varied. One of the most important of them is the *gravitational force*. And what would become of crystallization in the absence of such a force? Well, if the substance is homogeneous, there would be no problem. But,

imagine that what is required is an alloy of two different metals, one of which is lighter than the other and its melting point is lower. Then, the first metal, when heated, will melt sooner, while the second, before becoming liquid, will settle. Among various materials pairs like the one mentioned above are almost innumerable. Many their combinations could possess unique mechanical, electrical, and other useful properties.

Semiconductors can serve as an example. In the process of their making, a small quantity of admixtures is purposefully added to the basic material, say, silicon is added to germanium.

Many of us have watched telecasts transmitted from space, and it must have been weightless people and things that have surprised us most. Now, you can well imagine with what delight such shows are watched by those concerned with metallurgy and making of new complex materials. How splendid it would be to work in such space conditions! Well, their dream has come true.

The American spacecraft Apollo brought a small melting furnace into orbit. Experiments on melting were suggested by American scientists, while their Soviet colleagues worked out the research programme. It was conducted by both the Soviet and the American crew. The Soviet cosmonauts took along with them into space capsules with samples of various metals. Each capsule contained a model of one of the processes that are hardly feasible at ground-based plants, or are absolutely impossible on the Earth. In one of the capsules there was germanium enriched by silicon, the second had light aluminium stuffed with heavy little balls of tungsten. The third capsule contained aluminium powder.

As a result of melting germanium with silicon in space, a monocrystal of the alloy was formed, its edges having a spherical form. Such crystals are made use of in optics and electronics. It should be mentioned that the alu-

minium powder, after melting, became a highly porous material, because each of its tiniest particles melted separately under weightlessness. The distribution of tungsten in aluminium after they were heated up to the melting points was also found to be different from what it is on the Earth.

Thus, the experiment using the melting furnace became one of the first steps on the road of initiating space-borne production of hitherto unknown materials.

An eclipse made to order. It is possible to see the solar corona only at the time of the total solar eclipse, which is a rare phenomenon. Suffice it to say that the time total during which the corona was seen within the whole of the twentieth century amounts to less than six hours. During the eclipse, the Sun, the Moon, and the Earth must take quite definite positions in respect to one another, which, in accordance with the laws of celestial mechanics, does not occur often. Already for twenty years man has been sending out into space man-made planets and moons. Is it possible, then, to use them in such a way so as to stage a solar eclipse artificially? At present it has become quite possible to have a solar eclipse whenever it becomes necessary for scientific purposes.

Solar eclipses occur when the Moon finds itself between the Sun and the Earth and covers the visible disk of the Sun. But the artificial moons are too small to cover it. However, we all know that by approaching the object under observation its visible dimensions become greater. Does it mean that there is a way out? Why can't we bring the observer closer to the artificial moon? It is quite possible for spacecraft to do it.

Thus, the scientific programme of the then forthcoming Soyuz-Apollo mission was supplemented by an experiment which was called "Artificial Solar Eclipse".

On the fourth day of their joint flight, the cosmonauts

Leonov and Kubasov had again, and not for the first time, changed their profession. On that day they became astronomers. Soyuz played the part of the Earth, while Apollo was the Moon. Before the experiment began, the train of two docked spacecraft was orientated along the straight line directed towards the Sun. It must be mentioned here that Apollo was nearer the Sun. Then the spacecraft separated and, using the engines, they began to depart from each other. Apollo was thus covering the Sun, eclipsing it for those who were aboard Soyuz.

In the part of Soyuz turned to Apollo in the centre of the docking hatch there was a round window. During the experiment the lens of a photographic camera looked through it. Controlled by the programmed mechanism, the camera automatically took pictures of the solar corona.

When the distance between spaceships exceeded 200 metres, and the visible dimensions of the artificial moon, or Apollo, still remained twice larger than the diameter of the solar disk, the spaceships began to move towards each other for redocking. The eclipse, first produced by man himself, lasted for nearly five minutes.

Isn't it really simple? Let us not forget, however, that what we have here is a group flight of space vehicles flying over the planet at a speed exceeding 8 kilometres per second. Now, in the next experiment Soyuz and Apollo were not merely to depart from and then approach each other, but to do space aerobatics.

On top of the Earth. Space in which many of the artificial Earth satellites, including those that are manned, are in flight, is not outer space that surrounds the planets, the Sun, and the stars. At these altitudes, the presence of the Earth is still felt and the atmosphere is available. It is certainly not the dense air that supports winged airborne vehicles. In orbits 200-250 kilometres above the Earth's

surface, traces of the atmosphere consist of rare atoms and molecules. However, they do hinder the brisk movement of artificial moons, they are the first to encounter the solar and cosmic radiation, threatening to destroy all the living. This is why it is so important to know the composition and properties of the Earth's upper atmosphere. It is studied by automatic satellites and orbital laboratories. The crews of Soyuz and Apollo have also contributed to this research.

The atoms of oxygen and nitrogen are presumably the most elusive of all the particles comprising the outer layer of the air envelope of our planet. The fact is that they are averse to loneliness, and are quick to combine with those that are similar to them. Thus what we have before us is not single atoms, but whole molecules. Being unaware of the number of free atoms of these elements, it becomes difficult to answer a large number of questions pertaining to the physics of upper layers of the atmosphere that still remain unclear.

Soyuz and Apollo measured the concentration of these invisible particles at the flight altitudes. They did it with the help of rays, also invisible. There was a source of ultraviolet rays set up on board Apollo and their reflector aboard Soyuz. During the experiment the spacecraft were flying one above the other. Soyuz was positioned along orbit, while Apollo was above Soyuz, as if "standing on its head". The distance between the vehicles varied here from several hundred metres to one kilometre.

The rays, emitted by the Apollo source, having been reflected by the special mirrors mounted on Soyuz, returned to Apollo. Each time they twice covered the space between the vehicles and returned with impressions of encountered atoms upon them.

We have just been speaking of the atmosphere as something that serves to protect life on Earth. But, no matter how thick the air envelope may be, we shall never be

completely independent of outer space. The dependence is manifested in many different ways, but primarily in the periodic variations in the character of biological processes and phenomena. The Soviet and American spacemen helped scientists to get a little bit closer to the bottom of the problem.

The rhythms of life. It is spring. The fields are becoming green. Little leaves appear in the plots sown with peas. During daylight hours, the leaves tend to look up towards the Sun, but when night comes, they go down again, as if fatigued by labours of the day. The process is recurring in compliance with the Earth's rotation.

If we dig out one of the shoots and, together with some soil, transfer it into a dark room, we see that the plant won't change its habit. In total darkness the leaves will rise at noon and fall at midnight. This is, indeed, one of the most remarkable examples of the so-called *daily rhythm*.

When sea molluscs are placed in an aquarium, they long retain in their memory the rhythmicity of tides and react accordingly by opening and closing valves of their shells. This is called the *lunar rhythm*. It manifests itself in the life of a vast majority of plants and animals of the coastal zone. Other biological rhythms exist too: annular, monthly, and seasonal. All terrestrial life forms are dependent on them, and acquire the ability to orientate in time.

The question arises whether weightlessness, overload, and cosmic rays in outer space can have any deteriorating effect upon the mysterious mechanism of biological timing. Will the rhythm not be distorted? It was up to ray fungus to provide the answer to this question. It is a soil-dwelling microorganism, combining in itself the features of both bacteria and fungi. Thanks to the Soviet-American space effort it availed itself of the hospitality ren-

dered by Soyuz and Apollo. The fungus does not require any special treatment and easily lends itself to analysis. Its mycelium, in a solid nutrient medium, forms well discernible rings. A ring every day. In several days' time in a flat-bottomed cup, into which the fungus had been placed, it is possible to see a picture reminding us of a cross-section of a tree. The fungus has another merit which helped it to get a pass into space. It masters perfectly well the alternation of light and darkness, stores the rhythm in its memory, and goes on living in compliance with it, provided there is no impediment.

The annual rings help the scientists not only to determine the age of trees, but also to penetrate into their past. Thus, for instance, in arid and hot years the growth of trees is retarded, their rings, consequently, look thinner. It is exactly the same with the fungus. The rhythm of its life cannot possibly be divorced from the environment.

In the course of their joint mission the Soviet and American spacemen regularly photographed their cups with the fungi and exchanged part of them after the docking. The photos did not merely tell us how the fungus behaved in a state of weightlessness. They bore traces of cosmic particles that penetrated into the mycelium. Consequently, the experiment will help explain the impact of cosmic rays upon living organisms. The lack of knowledge here would impede the development of means to protect those who will set out for lengthy missions into outer space in future.

We should like to conclude this story on the first joint flight of two space vehicles belonging to different countries by quoting Alexei Leonov, pilot-cosmonaut, Hero of the Soviet Union. He said, "Let us hope that the technical foundation created by the Soviet and American specialists in the course of the preparation for our flight, the climate of friendship, which characterizes the attitude of all the participants of the Soyuz-Apollo Project to one

another, will constitute the basis for further international scientific experiments in space on a large scale and will promote the strengthening of peace on the Earth".

Unfortunately, what the spacemen were looking forward to, did not materialize. The plans of cooperation between the two great powers remained unrealized. Moreover, the US Administration has embarked on the militarization of outer space. Combat space-based systems began to be regarded as one of the key elements of the first nuclear strike. In accordance with a presidential directive issued in July 1982, the USA space efforts for the coming decade have been aimed at the development and deployment of new systems of weapons in orbits. More and more purely military tasks were assigned to the crews of manned vehicles of the Space Shuttle type. Furthermore, a new, space command has been set up as a part of the US Air Force.

In response to this, the USSR put forward a Draft Treaty on the prohibition of the use of force in and from outer space which was submitted to a regular session of the UN General Assembly. Once again the USSR has made it quite clear that it is a reliable and dedicated advocate of peace on our planet.

Space Paths of India

India is the first among developing countries that has embarked on a space programme. This work began soon after the space age set in. As far back as in 1957, in the year when the USSR launched the first artificial Earth satellite, a satellite tracking station was set up at Naini Tal observatory in the North of India. Five years later the Indian Space Commission was established. "There were people who doubted whether there was any need in space research for a developing country", wrote Dr. Vikram Sarabhai, the founding father of India's space pro-

gramme, "We, however, see the aim quite clearly... We are convinced in that we should not lag behind any nation in using the advanced technology for the benefit of Man and society in our country".

In 1962 a group of experts chose a site to construct a rocket launching station in Thumba, a fishing village at Trivandrum. Today Thumba can boast of an up-to-date launching complex, with an area of tens of acres.

Within the past twenty years India's space programme has made a most palpable progress. The first small rockets that went up only several kilometres, were succeeded by the four-stage 17-tonne solid-propellant SLV 3 rocket, which in 1980 and 1981 put into orbit two India-made satellites Rohini. The Indian scientists and engineers are planning to create more powerful boosters that would be capable of carrying into space much heavier satellites.

The first Indian satellite Aryabhata was launched in 1975 from a Soviet cosmodrome and by a Soviet rocket. The firstling of the Indian space efforts got its name at the suggestion of Mrs. Indira Gandhi, India's Prime Minister. It was a tribute paid to the memory of a remarkable Indian astronomer and mathematician, who lived fifteen hundred years ago. The satellite deservedly bore the name of the outstanding scientist. The equipment for scientific research installed aboard it carried out investigations on the front-line of astronomical science.

Aryabhata was succeded by Bhaskara I and Bhaskara II. Those were applications satellites doing work of practical importance for many national agencies by space-based remote sensing of India's territory. As is known, the country often suffers from devastating floods caused by long-lasting monsoons. The Bhaskara satellites were equipped with television systems and other devices intended to warn the people of the coming disaster, and to gather data for working out accurate weather forecasts.

Space-borne photos (Bhaskara I alone sent back about a thousand of them) were used by Indian geologists for exploring mineral resources, while agricultural institutions made use of the photos in predicting the yield of crops, and foresters studied the state of forest lands.

As a result of the cooperation with the Soviet Union a large community of young space scientists and engineers have been formed in India, who are successfully working at the development and construction of satellites, scientific equipment for them, flight control facilities, reception and processing of the information coming from orbit.

Links between the Soviet and Indian scientists are getting stronger all the time. The results and perspectives of their joint work are regularly discussed by the leading space experts at meetings alternatively held in both countries.

The development of telecommunication systems is particularly important for India. Space communication is not only convenient but, what is not less significant for a developing country, comparatively cheap. In 1983 the New Delhi TV centre began a nation-wide telecasting by means of a repeater installed aboard the Soviet sputnik Raduga. The latter was injected into a geostationary orbit to rotate synchronously with the Earth. The same year a satellite was launched from Space Shuttle, the American reusable vehicle, so as to ensure communications throughout the country and a direct telecasting to collective receivers in rural localities.

Appreciating the impact of space research upon the development of economy, India supports a world-wide exchange of experience in this field. Professor Satish Dhavan, Chairman of the Indian Space Research Organization (ISRO), Bangalore, speaking at the second UN conference on the exploration and peaceful uses of outer space in Vienna, said that space technology could serve as a powerful catalyst of all-round progress of developing

After skiing – Sharma and Malhotra in Star City near Moscow

countries. He emphasized the fact that India was quite ready to share its own experience with other nations, just as in its time the Soviet Union shared its experience with India.

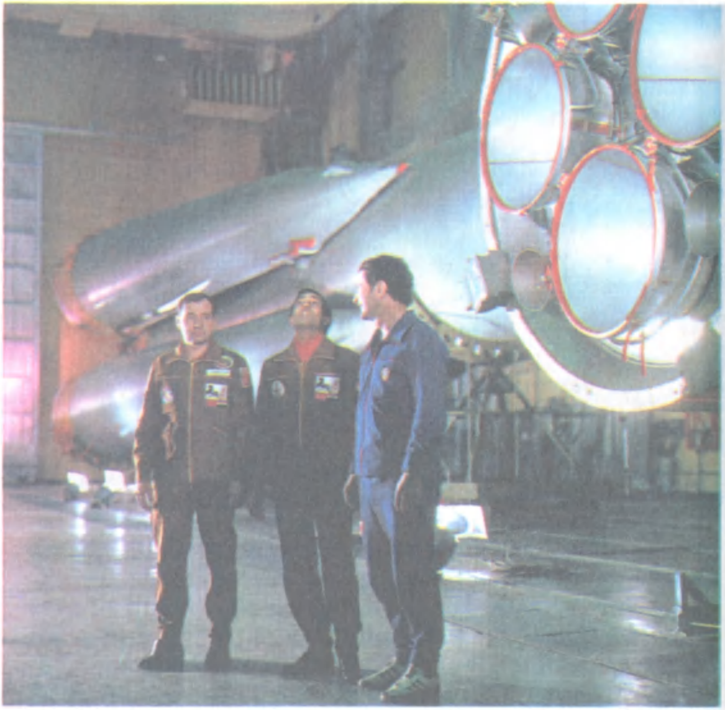
The pinnacle of the Indo-Soviet cooperation in space research has been the joint flight of Soviet and Indian cosmonauts. The idea was put forward by President Leonid Brezhnev during his visit to India. The offer was accepted with gratitude and received the full support of India's Prime Minister Indira Gandhi. Speaking before the Members of Parliament, she said that India could not keep aloof from the development of science. This is why the Indian people appreciate the opportunity rendered by the Soviet Union. It will enable Indian scientists to widen the scope of their knowledge which will find most tangible implementation in various fields of life.

On the eve of her visit to the USSR Indira Gandhi said

In the cabin simulator of Soyuz T – Malhotra with his colleague

that two Indian Air Force pilots, selected out of 150 candidates, had already arrived at Star City to join the Yuri Gagarin Cosmonaut Training Centre and started preparing for the joint flight.

"I should have been very upset, if I had not been chosen", said Rakesh Sharma to Indian and Soviet journalists at the press-conference in Star City. Both he and his friend Ravish Malhotra were quite willing to answer numerous questions. R. Sharma is a Squadron Leader and R. Malhotra is a Wing Commander. They both were born in Punjab (Rakesh Sharma in 1949, Ravish Malhotra six years earlier). The two future cosmonauts were trained at the National Defence Academy, Khadakvasla, as Air Force Cadets. Sharma had previously graduated



In the assembly building near the rocket (the Baikonur cosmodrome)

from the Nizam College, Hyderabad, and Malhotra completed the course of studies at St. Thomas High School, Calcutta.

Both Malhotra and Sharma are test pilots. They have flown various types of aircraft for over 3400 and 1600 hours respectively, so their flight experience calls for no special comment.

Ready for lift-off – Malyshev, Sharma, Strekalov

The preparation of the Indian trainees for the joint Indo-Soviet flight was divided into two phases. First, they learned the Russian language, acquainted themselves with fundamentals of space navigation, medicine, and biology, took special courses to study the stellar sky and spacecraft control systems. They were also flown on board special aircraft laboratories to get accustomed to weightlessness, were trained on simulators, and improved their fitness by physical conditioning and sports exercises.

After a short break, which the Indian pilots spent at home, the second phase in their preparations began. Now all the members of the two crews worked together. The Soviet and Indian cosmonauts were mastering the systems of Soyuz T spaceship, aboard which they were to travel into space; they studied the flight programme and

Launching of the rocket with the Soviet-Indian crew on board

experimental technique. They were learning to understand one another most accurately and with no loss of time.

The rocket carrying Soyuz T 11 was launched from the Baikonur cosmodrome on 3 April 1984. Rakesh Sharma set out to his space flight together with Commander Yuri Malyshev and flight engineer Gennadi Strekalov. The two Soviet members of the crew had already been in outer space before. In summer 1980 Yuri Malyshev and Vladimir Aksyonov tested the second spacecraft of the Soyuz T series. They checked the work of all systems in piloted and automatic modes and docked Soyuz T 2 with the orbital station Salyut 6. Several months later Gennadi Strekalov entered an orbit by Soyuz T 3. The station had been operating in outer space for more than three years by the time the crew of Leonid Kizim, Oleg Makarov and

Gennadi Strekalov came to Salyut 6 to repair some systems and thus prepare the station for the reception of a new team. G. Strekalov participated in a second space flight in April 1983. In that flight, during the approach of Soyuz T 8 to Salyut 7 divergence from the nominal mode was observed and the docking was abandoned.

Rakesh Sharma was accompanied by the experienced colleagues. In 24 hours after the lift-off, Soyuz T 11 approached Salyut 7 and the docking was accomplished. Next three circuits round the Earth must have seemed to the visiting crew the longest of their flight. Merely metal walls separated them from their hosts, but it was possible to meet them only after the checking of the docking unit pressure-tightness had been over. Then, at long last, the hatch lid was removed, and televiewers in the Soviet Union and India saw R. Sharma on their screens, swimming into a spacious compartment of the station.

Since then the six people on board had begun to work together. The presence of a professional physician Oleg Atkov in that small group made it possible to start, the very next day, medical experiments which were allotted an important place in the international flight programme.

According to medical evaluations, at least every third cosmonaut in first days of the space flight experiences disagreeable symptoms of the so-called "space sickness". This disorder, by the name of "motion sickness", is well-known to people who are not even remotely connected with space missions. One feels sick on board a sea-going vessel, or an air liner. Some of us cannot even travel in a car or on a train. A space flight itself and weightlessness which is always associated with it do not cause the sickness. But this is true only of those cases when the cosmonaut is at rest. It is quite clear, however, that a person who works cannot possibly remain immovable for a long time; so it is quite natural for him to move his head, which inevitably leads to the space sickness.

It would not be erring against facts to say that the space sickness has something positive about it too. After a three-day flight the disagreeable feeling passes off, and after 6 or 7 days it usually disappears completely. But even within this relatively short period weightlessness causes the cosmonaut no little troubles, and in a short flight the cosmonaut feels unwell from start to finish.

To treat a certain malady one must first of all know its cause. This axiom can wholly be applied to the space sickness. However, its origin is not quite clear yet. The Indo-Soviet crew was to make a certain contribution to the study of inner mechanisms of the sickness origin. For this purpose, the "Optokinesis" and "Anketa" experiments were carried out on the Salyut 7 orbital station.

The first of them cleared up the relationship between two systems of a human organism – vestibular and visual. This should be supplemented by a few words of explanation. To maintain a body in a particular position the human ear has a certain organ of equilibrium, or, as it is sometimes called, vestibular apparatus. Functioning of one part is determined by the gravitational force, while functioning of the other is conditioned by the acceleration of the whole body or the head. Naturally, in a state of weightlessness, the gravity-sensing part of vestibular apparatus starts functioning differently from what it does under terrestrial conditions and begins to send distorted signals to the brain. It is in this disagreement of two component parts of one and the same organ that many researchers see the cause of that particular form of space, or motion, sickness.

In those cases when the cosmonauts watch the Earth's surface, the situation worsens by the fact that the picture before their eyes is persistently moving in the course of the flight instead of remaining immovable. In other words, the eyes which could have helped the cosmonaut to determine the position of his body in space, also get

quite an unusual information, and instead of being helpful aggravate the motion sickness. Thus, between the visual and the vestibular systems there also emerges a disagreement. It was to understand its development that the "Optokinesis" experiment was conducted.

Various geometrical figures appeared before the cosmonauts on the screen of the on-board video tape-recorder. It was a kind of imitation of the running Earth's surface as seen through the windows of the orbital station. The cosmonaut watched the screen, remaining quite still or slightly moving his head at a given pace. In the process performance characteristics of both visual and vestibular systems were recorded.

As the task of the "Optokinesis" experiment was to gather experimental data pertaining to development of the motion sickness in space, the "Anketa" (questionnaire) experiment was a complementary investigation, with the cosmonaut giving a subjective evaluation of his state before, during, and after the flight. The questionnaire helped members of the international crew concentrate on their perceptions related to the space sickness and draw their attention to perception dependence on the flying conditions and the kind of work being performed at the moment.

The results of these investigations have a great importance in elucidating all possible causes of the motion sickness in space flight, in elaborating appropriate preventive means, in working out recommendations for the cosmonauts conducting visual observations, and can also be employed in perfecting the methods of selecting and training the cosmonauts.

If a person is placed on a rotating table with his head down, his heart rate could change which could even be followed by faintness. The phenomenon in question can be registered with every fifth person found to be absolutely healthy in all respects. The fact is that in an upside-

down state the blood circulation undergoes marked changes. When we are in a normal upright position (as is the case when we walk, stand or sit), the blood, on its route to the heart, has to overcome an additional resistance caused by its own weight. When, however, the head is down and the feet are up, weight, conversely, makes it easier for the blood to return from the veins of the legs, hampering its outflow from the heart. This brings about the above-mentioned reaction.

In weightlessness the blood has no weight, hence its distribution in the organism differs from what it is under normal conditions. What happens is that its amount in the upper part of the body increases and it rushes to the head. To alleviate the cosmonauts' state, particularly disagreeable in first days of the flight, various measures of prevention are tested. The "Prophylaxis" experiment conducted by the members of the international crew was meant to assess the efficiency of some of the measures.

The Soviet space medicine has worked out effective methods of investigating and suppressing the redistribution of blood in weightlessness. As far back as in the days of Salyut 1 there was a special on-board installation in the form of a "barrel", from which air could be pumped off. The cosmonauts get into the installation waist-deep, the blood rushing into the zone of low pressure, i. e. from the upper to the lower parts of the body.

Salyut 7 is also equipped with special prophylactic means. During first days of the flight, inflated cuffs made of thin rubber were used for the purpose. By regularly filling them with air, the cosmonauts tightened their hips, thus impeding the blood outflow from the legs. The effect was quite favourable. To speed up the recovery, special medicines were administered. They dilated the blood vessels and improved their tone.

It has become a well-established fact that physical exercises can serve as a reliable means of preventing the unfa-

vourable consequences of weightlessness. The proverbial inventor of the bicycle could hardly have thought that his brain-child would find itself in outer space. Well, no one would call the veloergometer a real bicycle. It is an exerciser specially designed to measure off accurately the physical load. As the cosmonaut is "cycling", the vital systems of his organism are closely telemetered from the Earth. The self-checking is performed as well. In the Indo-Soviet flight, the cosmonauts were taking cardiogrammes of one another. The data were recorded not on paper, as is the usual case in hospitals, but on magnetic tape, which was brought back by the crew for a subsequent analysis.

As the commander and the flight engineer were pedalling, Rakesh Sharma was doing his yoga exercises. In excercising, as a rule, the cosmonauts are moving actively. However, our muscles are fit not only for this kind of active work. When we are standing, sitting or even lying, there are quite a few muscles that continue to work and support the body or its certain parts in a particular position. This is work too, though static and not dynamic. At the same time, the muscular activity, as always, is closely connected with the functioning of the internal organs. The extent to which this connection is important for the organism can be seen from the examples adduced below.

During static exercises, a heightened or lowered degree of acidity of the gastric juice becomes normal, the coagulation increases, with white blood count rising. There occur other changes in the blood too, they exemplify the rallying force of its protective properties. This characteristic feature of static exercises allows them to be included into therapeutic gymnastics.

There is every reason to refer the yoga exercises to static training. The five postures, or *asanas*, which were Rakesh Sharma's "daily dozen" made many of the mus-

cles and muscle groups of the back, hips and knees do quite a bit of stretch work. In the conditions of a space flight, when many parts of the body are doomed to either full or partial inactivity, the yoga exercises are supposed to be an adequate remedy.

If in the result of the Indo-Soviet experiment the efficiency of static exercises in physical conditioning is verified, then they may be recommended to other space crews along with active exercising. It should be pointed out that the combination of static and dynamic forms of physical exercises corresponds, in the best possible way, to the very nature of our motor system.

Besides being testing a prevention of the negative effect of weightlessness, the yoga exercises were used in studying the muscular activity during the flight. The great Russian physiologist Ivan Sechenov attached great importance to muscular activity in the life of man, "Whether it is a child's laugh at the sight of a toy, Garibaldi's smile when being ostracized for loving his country too much, a girl's thrill in her first whirl of love, or Newton's creation of his universal laws when writing them on paper – all, in the long run, are muscular activities". In other words, it is not only walking, running and manual labour that are immediately connected with muscular work but also the expression of our emotions and mental activity as such.

To get a better understanding of muscles functioning under conditions of a space flight, the yoga exercises were subjected to analysis. Each time the Indian cosmonaut did his *asana*, a number of parameters of motor and electrical activity of the muscles were telemetered. Having obtained such data, medical specialists are in a position not only to work out optimal sets of exercises for cosmonauts, but also introduce certain amendments into athletic training and therapeutic gymnastics.

During the flight of the international crew, particular attention was directed to the cardiovascular system. This

calls for no extensive comment. First, it is one of the most "responsible" systems of the organism, then it is so closely connected with the other systems that by its deviations from the norm one can foretell condition of the whole organism, and lastly, performance of the circulatory system can supply us with information sufficient to predict how the cosmonaut will feel next and how he will cope with difficulties of return to the Earth, when weightlessness is first succeeded by re-entry overloadings and then by a normal force of gravity.

In the programme of the Indo-Soviet flight there were two experiments specially intended to investigate the cardiovascular system – "Vector" and "Ballisto". In the first of them the functions of the heart were studied by assessing its electrical activity. For this purpose the cosmonauts employed a portable cardiograph, fabricated by Hindustan Aeronautics Ltd. (HAL). The cardiogrammes were taken in a state of rest and in a state of physical activity (during cycling on the veloergometer).

The first cardiogramme to be taken under weightlessness was that of Laika dog as far back as in 1957. Since then the method has been extensively used in the training of cosmonauts and medical check-up on their return to the Earth. In the "Vector" experiment, besides electrocardiogrammes, recorded also were vibrations of the chest caused by the heart beats. This gave additional data characteristic of the cardiac work.

The "Ballisto" experiment was concerned with the cardiac work depending on the change of its position in the chest as a result of weightlessness. For this purpose, recorded were displacements of the body caused by the heart activity. In our everyday life such trifling displacements are unnoticeable. Under weightlessness, however, they can be detected and recorded by special sensors, attached to various parts of the cosmonaut's body. As a result, we obtain new information on the heart contrac-

tion force, as well as on how the work of right and left halves of this living motor is coordinated under weightlessness.

Besides the investigations of various systems and organs of the human organism, the programme of the Indo-Soviet space flight also included a research into the psychological state of the participants of the mission. We live on the Earth, and are surrounded by our relatives, friends and colleagues. We all work, most of us are cinema and theatre-goers, to say nothing that we go in for sports, make merry and enjoy vacations in accordance with our habits and national traditions. But the moment we set out on a space flight, we are immediately deprived of all this. We lose touch with all that we have been accustomed to. We enter the confines of an orbital station with its pressurized modules; the environment is narrowed down to several members of a crew. Periods of work and rest are wholly determined by the rigid programme of the space mission. All this takes place under weightlessness when we have to handle things by first swimming up to them, like fish, when there is nothing solid under our feet and when the top and the bottom change places according to the position we take.

It is quite natural that such highly unusual circumstances are to be accustomed to or, as our doctors say, we have to get psychologically adapted to them. The process is peculiar to the individual. For some people it is fast and hardly noticeable, while for others it is slow and complicated. In international crews the psychological adjustment becomes more difficult since in addition to all mentioned previously there appear national peculiarities, different attitude to living conditions, and language barrier.

No one but the cosmonauts themselves know the multifarious scrapes of the space flight and what they do to one's psychological state. But it is not always that they

can give the problem enough thought. Their everyday schedule is so crammed that there can hardly be any time left for thinking of this aspect of the life in orbit. If, however, someone does manage to do it, the assessment of his own state does not always fall short of an error.

To obtain objective data on this problem the psychologists of the USSR and Poland, before the joint Soviet-Polish space flight, drew up a special questionnaire referring to body movement under weightlessness, sleep, appetite, individual interests of the cosmonauts, their attitude to their colleagues, self-rating, formation of working skills, and peculiarities of communication by speech or gesticulation.

After the Soviet-Polish flight the medical-and-psychological questionnaire was used by other international crews. The scientists of each country-participant of a space mission usually interpolated it, thus perfecting this specific and rather unusual set of questions. The Indian psychologists have also contributed to it. Rakesh Sharma together with his colleagues made daily evaluations of their mood and condition according to twelve features such as the degree of emotional manifestation, level of anxiety, and so on. In answering the questions, the cosmonauts used five marks to describe their state at the moment of check-up, the relevant, in their opinion, mark being entered into the observation log-book.

The results of the experiment will find their application in regulating the regimen of work and rest on board the orbital platforms as well as in elaborating recommendations to improve the living conditions in forthcoming space flights of short and long duration.

The investigation of India's natural resources held a prominent place in the course of the joint flight. The cosmonauts observed and photographed the territory of India. The scientific value of any photograph is usually established by the number of details distinguishable in it,

or, as a specialist would put it, by the "resolution". The more details the photograph "allows" us to see, the better it is. However, this is not always the case.

Any specialist in forestry would be glad to discern every single tree in a photograph taken in orbit which is hardly possible. But what does become possible is to cover a vast territory of the greater part of Western Europe or India within the confines of one single picture, so that an experienced observer could discern the main structural features of the Earth's crust in the region. Lack of small details that would mask large geological objects only makes for better discernability.

The space height makes it possible to bring together individual terrain features that seem isolated at a close-up. It becomes possible to amalgamate disjointed parts into a qualitatively new and complete picture. This accounts for the fact that space-borne photographs reveal, through a fairly thick cover of later deposits, the in-depth structure of the Earth's crust. And the higher the observer (either a spaceman or an artificial satellite) gets, the deeper the insight becomes.

So far, science has not been able to furnish any coherent explanation of this phenomenon. However, this does not hamper geologists to use space "X-ray facilities" for practical purposes. It would be hardly feasible to assume that the deposits of mineral resources lend themselves to discovery straight from space. What we have in mind here is something quite different. From orbits one can discern those geological structures, in which deposits are possible, e. g. deep fractures in the Earth's crust. Spacecraft photography makes it possible to have a better understanding of the regularities in the crust structure and, as a result, the occurrence of minerals useful for Man.

To explore the India's territory, the Indo-Soviet crew made use of various photographic cameras. One of them is a multispectral MKF-6M camera designed by the spe-

cialists of the USSR and GDR and fabricated by the people's enterprise Karl Zeiss Jena, GDR. It is only tentatively that we can call "camera" an installation weighing 200 kilogrammes. Actually it is a highly complicated system with six lenses, complex mechanism, and no less sophisticated electronic control. Another device is the KATE-140 cartographic camera made in the USSR. Each its frame covers a square on the Earth's surface with its side measuring several hundred kilometres and with the resolution of tens of metres.

The photographs taken from the orbital station will not be the first space-borne pictures of India's territory. Suffice it for us to recall the Bhaskara satellites, that had been long investigating the country's natural resources. But those photos were taken by automatic devices, while aboard Salyut 7 hand-held cameras are operated by the cosmonauts. The difference is enormous. Before snapping the shutter, the cosmonaut makes a visual study of the object, chooses the more suitable lighting conditions, decides which camera and what film are to be used. It was this that the Indian geologists had in mind when they were elaborating the research programme for the Indian cosmonaut.

In the course of the "Terra" experiment on remote sensing, R. Sharma and his Soviet friends have taken more than fifteen hundred pictures. What came into view were Andaman, Nicobar and Laccadive Islands near the shores of which oil deposits are supposed to be found in the shallow-water areas. Then came the ring structures, large forest areas and afforested plots in the central part of the Indian peninsula, the Gangetic delta and the Himalayan glaciers that feed many rivers of the country. The desert zones of India were also studied including temporary watercourses, as well as the area of the Indian ocean, where the biological productivity of certain regions was determined.

At the same time as taking pictures in orbit, similar observations and photography of the same areas were made using specially equipped laboratory aircraft, and ordinary ground-based expeditions were sent there as well. The results of this integrated research will be used to make out revised geographical maps and land utilization maps of India. The photographs delivered from orbit will be found useful in exploring the ocean and coastal zone. They will be also employed to study the flow regime of rivers with the aim of establishing sites for the construction of hydroelectric stations and discovering new possibilities for the irrigation of arid lands.

Rakesh Sharma says that looking from outer space it is easy to discern India since the Earth's surface resembles very much a geographical map. Flying over the whole country from south to north within several minutes, the cosmonauts had enough time to see the blue of the ocean waters washing its shores, the emerald green of the central regions, and the snow white Himalayas. India is fascinatingly beautiful. But it was not only the admiration of the Indian cosmonaut at the sight of his wonderful motherland that made him single out the "Terra" experiment from other items of the research programme. In the investigation of the India's natural resources he saw how much benefit the Indian people could derive from the space research. We find the thoughts expressed by Rakesh Sharma to be fully congruous with what Swami Vivekananda, Indian outstanding humanitarian, thinker and public figure said when he called the land of India his highest sky.

The third section of the scientific programme of the Indo-Soviet space flight concerned materials science. There were several material-processing installations aboard Salyut 7. One of them, "Isparitel" was intended to study the possibility of coating various surfaces with metallic films and other materials in space. This can become use-

ful in the future during repairing work, when the outer coatings of space vehicles have to be renewed. It is a well established fact that in the course of long-time space flights the outer structural parts are subjected to the deterioration due to micrometeoric bombardment, cosmic radiation, and sharp variations in temperature. The construction of future space power stations and huge reflectors for illuminating the Earth in the night-time will require to set up many-kilometre reflecting planes in outer space, and it is with thin metallic film that the mirrors of big orbital telescopes will have to be coated.

The "Isparitel" installation has been successfully tested in space for a long time. During the Indo-Soviet flight it was used as a kind of a melting furnace. For this purpose, those who designed it, research workers of the Paton Institute of Electric Welding in Kiev, had prepared a special unit. During operation, it was placed in an open outwards air-lock chamber, and thus the process of melting was conducted under vacuum of outer space.

The Indian scientists put forward a suggestion to study the peculiar conditions of heating and cooling in space, in other words, the conditions under which metal alloys can gain quite an unusual structure, improving their strength and other mechanical properties, resistance to radiation and high temperatures. In terrestrial surroundings, the structure of this kind is obtained by exerting quite a bit of effort and only in thin superficial layers of metal. Under weightlessness the multitude of alloys were expected to be just such as the specialists wished to see it. At the suggestion of the Indian party a silver-germanium alloy (well-known to Indian researchers) was chosen for the experiment. On returning from space, Rakesh Sharma with his colleagues brought back several quartz ampoules containing the alloy produced in orbit. They were handed over to scientists for laboratory tests and final report on both structure and properties of the new material.

Back in Star City. Laying flowers at the monument to Yuri Gagarin

On the morning of 11 April 1984 Soyuz T 11 landed in the steppe of Kazakhstan. There was something symbolic in that the event remarkable for the people of India occurred on the eve of the Cosmonauts' Day, the day on which 23 years ago Yuri Gagarin ended his historic space flight. During his visit to India, the first cosmonaut spoke of the time when a representative of the great Asian power would also go into space. And now the time has come. The Soviet people are happy that this space flight

became one more manifestation of the ever strengthening USSR-India friendship, the fact which has been substantiated by Prof. U. R. Rao, Director of ISRO, who said that Rakesh Sharma's space mission was a trial run of the Indian Space Programme just as the launching of the first Indian satellite Aryabhata. Prof. U. R. Rao expressed India's gratitude to the Soviet Union for assistance in space exploration, and said that India would continue to extend its space efforts.

A Robot in Orbit

Satellites and the weather service. The Soviet vessel, doubling the African continent from the south, was approaching the Mozambique Channel. The ship's radio operator received an alarming radiogramme. The weather forecasters from far-away Moscow warned that a powerful tropical cyclone was heading towards the vessel. Their advice was to avoid the encounter by going round Madagascar from the east. But the bulletins of local coastal weather stations said that a hurricane was approaching the island from the east.

The ship steered east. Several days later, it was caught in a minor storm and, having avoided any grave consequences, it was safely continuing its voyage. At that time, however, a tropical cyclone was raging near the African shores.

How was it, then, that the Moscow weather forecasting service could be more accurate in assessing the meteorological situation than the local specialists? The answer is that the Moscow forecasts were supported by the artificial Earth satellite Cosmos 184. The photographs taken by it over the Indian ocean and received in Moscow showed that the eastern hurricane was less dangerous than the cyclone.

The artificial Earth satellites allowed people to look for

the first time at their own planet from afar. The first Soviet weather satellite Cosmos 122 was put into orbit on the 25th of June 1966. Less than a year later the space weather station Meteor started to function. It consisted of three satellites. This system has been functioning continuously and is regularly supplemented by new satellites of the Meteor type. They are put into circular orbits at approximately 600 kilometres above the Earth's surface and help the meteorologists to forecast weather more accurately.

It takes the space weather scout a little more than an hour and a half to orbit the Earth. The angles between the orbital planes of Soviet weather satellites and the equatorial plane are close to 90 degrees. Thus, the satellites, at each revolution round the Earth, pass over its polar regions. Since the Earth rotates round its own axis from west to east, each successive turn is found to be above more western regions of the planet than the preceding one.

How does a space meteorological station work? In the picture that follows you can see a satellite of the Meteor series. Its equipment must operate as long as possible. That is why the designers adopted solar cells as a source of power supply. The altitude control system of solar-cell panels all the time keeps their surfaces perpendicular to the sunbeams. On this condition, as has already been said, the solar-cell current will be maximum.

The satellite itself consists of two cylindrical modules. In the smaller one there are instruments for meteorological observations, and in the larger one there are service and auxiliary systems. In flight, the satellite is orientated. Its main axis is all the time directed exactly to the centre of the Earth. While the orientation and stabilization of spacecraft are mainly conducted with the help of jet engines, the fixed position in space of the weather satel-

lites is achieved and maintained by several spinning flywheels. Forces to control a space vehicle are developed with the change in spin velocity of the flywheels. The latter are set into motion by energy of solar cells, each flywheel being a massive rotor of an electric motor. Thus, the long-term work of the attitude control and stabilization system is secured, since the reserves of solar energy in outer space are inexhaustible.

The satellite is "viewing" the daylight side of the Earth with two television cameras. Their lenses directed downwards are set at a small angle in respect to each other. Thus, the scope of visibility becomes nearly twice as large. Television cameras, working all the time during the flight, see the band of the Earth's surface or of its cloud cover 1,000 kilometres wide and up. The image thus received is recorded on a magnetic tape, and when the satellite is flying over the information reception stations, it is transmitted to the Earth. When the satellite comes out of the Earth's shadow, first sunbeams automatically turn on the television equipment.

But the space-borne weather forecaster does not stop his observations even over the night side of the planet. Now the infrared equipment replaces the television. Its "eye" swings like a pendulum perpendicularly to the plane of the satellite's flight, thus "viewing" the band of the Earth's surface of exactly the same width as the television cameras do. Infrared receivers measure the thermal radiation of the Earth's surface. The clouds are always colder than the surface of the Earth. Hence, cloud formations, e. g. typhoons, cyclones, etc., are clearly distinguished in these pictures. During the polar night in the northern and southern regions of the planet only the "night eyes" of a weather satellite allow us to see the clouds.

Communication satellites. Demands for telephone communication are growing fast. But cable-laying over

thousands and thousands of kilometres is both time and labour-consuming. Besides, it is also very expensive.

Radio does not always prove to be helpful either. Some twenty or thirty years ago, when radio stations were comparatively rare, they worked on long, medium, and later on short waves. Now the world is practically congested with radio stations, and it becomes impossible to use these wave bands without interfering one another. That is why radio operators resorted to ultrashort waves (USW).

However, these waves, capable of transmitting radio signals with practically no disturbances, have quite an obvious deficiency: they propagate in straight lines, similar to a beam of light, and are almost not reflected from the ionosphere. With the advent of artificial Earth satellites, an idea was conceived of using them as radio mirrors for USW reflection. The idea was by no means original. The Earth satellite had already been employed for this purpose, though it was not artificial but natural. Experiments involving radio communication via the Moon had been conducted as far back as in 1948. In 1964 it was the Moon that successfully promoted radio communication between the Jodrell Bank Observatory in England and a Soviet observatory near Gorky. But radio communication using reflection from the lunar surface is only possible within a very limited part of the day, when the Moon is visible from two points in communication at a time.

An artificial Earth satellite, put into a specially chosen orbit, can be within the acquisition range of required points much longer. The communication satellite of this kind, Echo 1, was launched in the USA in 1960. This ball-shaped satellite reflected almost all the radio waves directed at it from the Earth, while the Moon reflects only 7% of the received energy. But both the natural and the artificial Earth satellites were quite indifferent as to where the reflected energy was to be dispersed. This

accounts for the fact that only an insignificant part of the power radiated by the transmitter returned to the input of the ground-based receiver whose function was to get the signals reflected from the satellite. This and other drawbacks made the scientists abandon such passive communication satellites.

On the 23rd of April 1965 the first Soviet communication satellite, the active repeater Molniya 1 was launched. For many months it was a reliable "go-between" in transmitting TV programmes and regular telephone communication between Moscow and Vladivostok. On the 14th of October 1965 the second satellite was launched, thus initiating an experimental system of long-distance two-way telecommunication. The third Molniya satellite was used for exchanging TV programmes between the USSR and France.

Within the period of some years that passed since the first Molniya was put into orbit, a large number of satellites of this type have been launched in the Soviet Union. Communication satellites Molniya 2 and Molniya 3 are doing their bit of work in outer space. The telecommunication system employing the Molniya satellites works in the following way. With the help of a pencil-beam antenna the transmitting station sends out signals in the form of a narrow wave beam to the satellite. The signal received by the transceiving antenna of the satellite is directed to the radio receiver. There, the signal is amplified and the satellite's transmitter sends it to the Earth where it is received by the reception station.

Look at the picture of Molniya. A sealed cylindrical body contains the repeating equipment consisting of a sensitive receiver and a powerful transmitter, as well as various auxiliary systems. The satellite accommodates a correcting engine, microengines of the attitude control system, solar-cell panels. The solar panels are recharging the storage batteries that provide power supply to all the

equipment. On the outer part of the satellite's body there is also a radiator-cooler and a panel heater of the thermoregulating system. The required inside temperature is automatically maintained at all times.

While the solar-cell panels must "look" at the Sun all the time, the unfolding "umbrellas" of parabolic antennas must also uninterruptedly see the Earth. That is why the satellite, by signals of the Earth-orientation sensor, turns and directs its antennas towards the Earth. The accurate guidance of the antennas in the direction of the Earth is concluded by turning the rod carrying the umbrella. Then the taken position of the satellite is stabilized.

The 50th Anniversary of the Great October Socialist Revolution was marked by putting into operation "Orbita", a system of stations for superlong-distance television. It is only in this country that such a wide network of ground stations for space communication has been set up. Molniya has become a communication link between Europe and Asia, or between Europe and the American continent.

Right after Molniyas there followed new communication satellites of the Raduga type. These vehicles, as distinct from their predecessors, move at the altitude of approximately 40 thousand kilometres in a circular orbit in the equatorial plane synchronously with the Earth's rotation and for this reason seen immovable to the ground-based observer. An orbit of this kind is called *stationary*. The Raduga satellites are serving the regions of Siberia and Far North.

However, for the reception of Raduga signals, as well as for the communication with Molniyas, large antennas and fairly complex reception stations are required. The new communication satellite Ekran, also put into a stationary orbit, has on-board transmitters of enhanced power. Their signals can be received on the Earth by

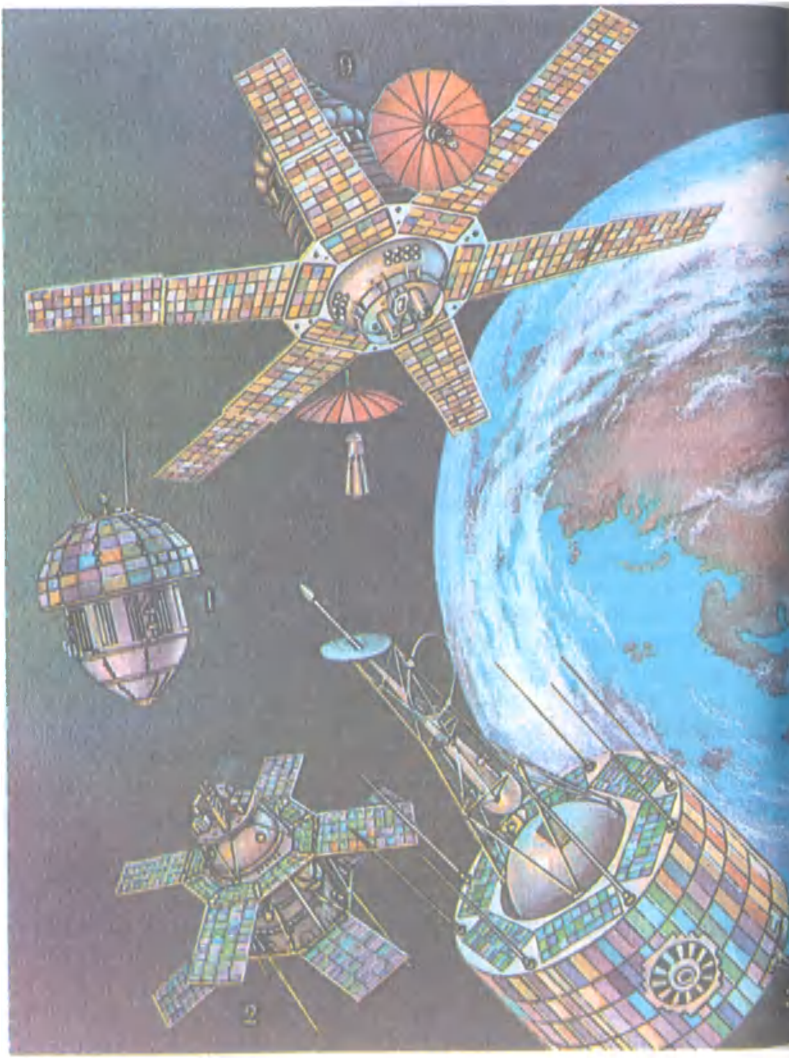
comparatively simple and inexpensive aerials. Thus, thanks to the Ekran satellites, TV programmes from Moscow can be watched by televiewers in remote and small localities, where the construction of the "Orbita" stations would not pay off.

All communication satellites are used not only for repeating telecasts, but also for telecommunication.

Satellites functioning as beacons. From time immemorial travellers, when they lost their bearings, were guided by the celestial bodies. Now, too, every navigator has either a sextant or some other instrument to take his bearings using the stars, the Sun, and the Moon. But what is to be done in case of a dense fog or overcast? The way out has been recently discovered. It was radio astronomy that proved to be helpful here. The fact is that radio radiation of the celestial bodies cannot be hampered by cloud cover. The receiving antennas allowed navigators to see the sky through clouds. However, the accuracy of radio sextants proved to be not very high and cannot be relied upon completely. It was special navigation satellites that became trustworthy beacons for navigators in the air and on the sea.

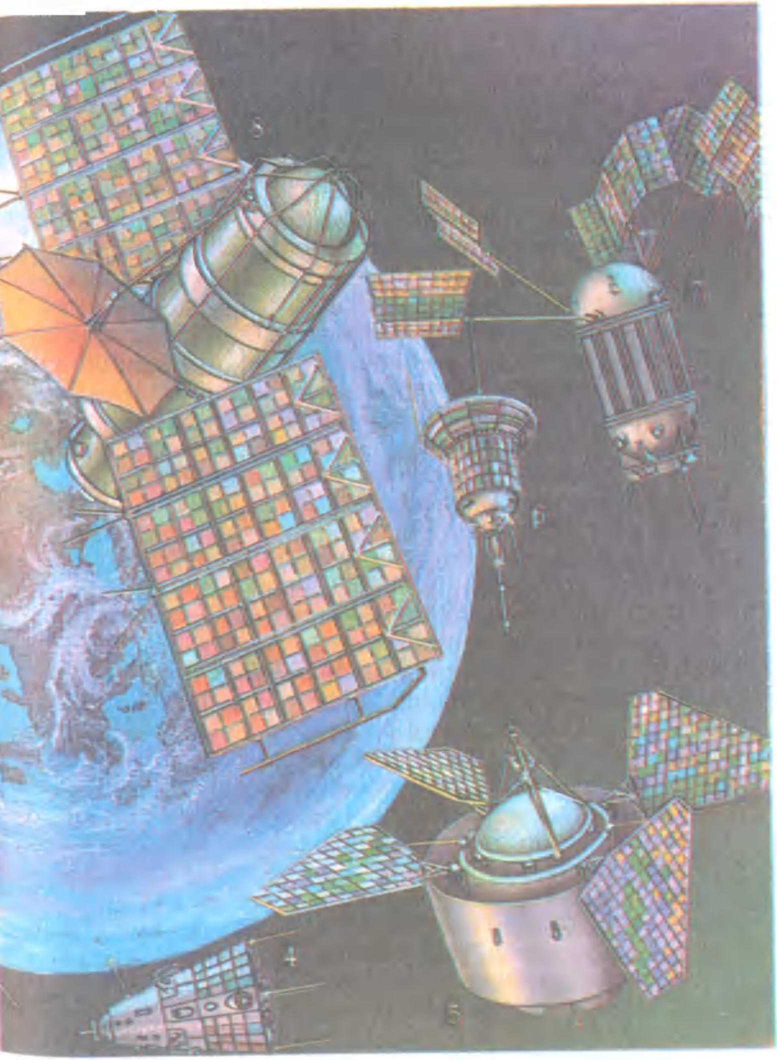
A terrestrial object or a celestial body can serve as a reference point only if its position at the Earth's surface or in respect to our planet is known precisely. The position of a satellite in respect to some point of a given surface can be shown with a high degree of accuracy at any moment. It is only necessary to know the parameters of an initial orbit of the satellite and the laws of celestial mechanics that govern its movement.

The number of navigation satellites and their orbits are chosen in such a way that those "landmarks" in space should frequently pass over regions of the Earth's surface within their range of coverage. The satellite-borne radio transmitter emits signals from time to time. As the satel-



Some artificial Earth satellites:

1, 3 – Cosmos series; *2* – Intercosmos; *4* – the third Soviet sputnik; *5* – Proton-1



6, 7 – Electron 2 and Electron 1; 8 – Meteor; 9 – Molniya

lite flies over, the radio station on board a ship or a plane determines the satellite's angular coordinates – altitude and azimuth – or the distance to it. Now that we know the position of the satellite in respect to the observer and its coordinates at the moment of communication, it is not difficult to determine the coordinates of the observer himself, i. e. the ship or the plane.

As far as its own coordinates are concerned, the satellite reports them itself. For this purpose they should have been calculated beforehand and sent by radio to be stored in the satellite's memory. When the satellite appears above its "own" region, it automatically "recollects" the stored data and transmits them to the Earth.

The information received from the satellite is put into the ship's or plane's computer, which yields the geographical coordinates the navigator is interested in.

The artificial Earth satellites serve the cause of science. On the 16th of March 1962 the Soviet Union began launching satellites of the Cosmos series according to the programme compiled by the USSR Academy of Sciences. The inventory of tasks set before the satellites of this series is copious. The satellites study the magnetic field and radiation fluxes near the Earth, investigate the X-ray and ultraviolet radiation of the Sun, carry out various biological experiments.

Besides, the Cosmos satellites have become a proving ground in space. A large number of design problems of space engineering were solved owing to them: protection of spacemen from dangerous radiation, design of structural elements with regard to space conditions, automatic docking in orbit, re-entry into the atmosphere and landing, to mention only a few. Even the second vehicle of the Cosmos series sported the skills of a test pilot. The attitude control system and new ionic sensors were tested in operation aboard the satellite.

Satellites of the Cosmos series were in the Sun-watch

more than once. Cosmos 166 and Cosmos 230 scrupulously studied the life of the Sun. One of their series numbered 348 analysed the Sun-Earth links; in particular, the impact of the solar activity upon the Earth's atmosphere.

In the solar exploration, several other Soviet unmanned spacecraft took part. Among them were Prognoz stations. The scientific equipment installed on those satellites, investigated gamma and X-ray radiation of our star, streams of solar plasma and its interaction with the magnetic field of the Earth. The exact forecast of solar activity, methods of which were elaborated using experiments on board the satellites, is of great importance for theorists and observers.

In 1964 the Soviet Union launched satellites of the Electron series to investigate the radiation belt and magnetic field of the Earth. That time one carrier rocket injected two satellites into different orbits. This enabled the scientists to study the outer and the inner zones of the radiational belt simultaneously.

Scientific hardware to examine cosmic-ray particles of high and superhigh energy was delivered into near-earth orbits by the Soviet stations Proton. On these vehicles, the instrumentation payload alone exceeded 12 tonnes.

It goes without saying that only large scientific institutions and powerful industrial enterprises can cope with the task of producing such heavy and complicated spacecraft. Small satellites, however, can be designed and even fabricated by groups of students. It has already been mentioned above that "Iskra 2" launched from the orbital station Salyut 7 was the result of student research. Some time before that even two "Radio" satellites intended for amateur radio operators had been put into orbit by the "full-sized" satellite Cosmos 1045.

Satellites for amateur radio communication were launched in the past too, for example, the space repeaters "Oscar" manufactured commercially in the USA. But

those vehicles were launched, and what is more, used one at a time. The launching of Soviet satellites, however, made it possible to have a system of three objects in orbit at the same time. Why three and not two? The fact is that on Cosmos 1045 itself there was a set of amateur radio equipment similar to the one on board the "Radio" satellites that were launched from it.

There was every reason for radio amateurs to rejoice. On launching special satellites, the distance between transmitting and receiving stations could become several times greater, which, in its turn, widened the effective range of every amateur radio operator. Suffice it to say that 26 thousand collective and individual amateur radio stations were operating in the Soviet Union at that time, a fact that calls for no further comment to express the nation-wide acclamation of the event.

The "Radio" satellites were made by amateur radio operators and students of higher technical schools. Well, it is certainly difficult to compare the production capacities of factories with those of students' workshops and laboratories. However, it cannot be denied that the satellites were produced in compliance with all the requirements for spacecraft. All this speaks in favour of enormous potentialities of amateur creative activity.

To produce satellites was only half the story. As has already been said, special ground-based monitoring stations are necessary to control them. The stations have been also built solely on the initiative and the means provided by public efforts.

In one of the wide Moscow streets there is a dwelling house that would appear quite ordinary were it not for unusual antennas sticking out on its roof. Here, in one of the flats allotted to amateur radio operators, accommodated is the reception-control centre. A similar centre was set up in the Far-Eastern part of the country – in the town of Arsenyev, the Primorye Territory.

The students that took part in the development of the "Radio" satellites called them educational and experimental. The name can fully be justified, if we take into account the fact that special academic work involving satellites was being conducted in the laboratories of higher schools. This project has enabled students for the first time to establish communication through space and to study cosmic phenomena with the aid of radio waves.

In studying outer space, the Soviet Union closely co-operates with all the socialist countries. Satellites of the Intercosmos series are regularly put into orbits by the Soviet rockets. The satellite-borne scientific equipment, experimental technique, flight programme are worked out jointly by scientists of the socialist countries. Each flight adds to the results that have previously been obtained by contributing new information on the objects under study. The Intercosmos satellites have quite a lot of objects to deal with, e. g. the Sun and its space environment, the air envelope and magnetic cage of the Earth, aurorae and many others.

By launching Intercosmos 15 the socialist countries have begun a new stage in their joint exploration and uses of outer space. As distinct from all the preceding satellites, this vehicle is an automatic multipurpose orbital station designed for carrying out research on a wide scale. The station distinguishes not only in that it can contain a variety of instruments, but also in that it is the first to be equipped with the unified telemetric system for transmitting scientific information directly to the reception centres in the countries that participate in the international programme.

The number of countries producing automatic space probes is still rather limited. To make instrumentation for spacecraft and to fabricate satellites are two different things. As has been mentioned above, besides scientific equipment, space robots have a whole set of complex on-

board systems to provide for the attitude control, stabilization, operation of engines, temperature conditions in the compartments, power supply, etc. For this reason, a country's development of own satellite should be regarded as a qualitatively new step in the development of the national space programme. Following the leading space powers, this step was made by the Czechoslovak Socialist Republic.

The Czechoslovak satellite Magion was launched together with the Intercosmos 18 satellite. During their joint flight, the specialists of Czechoslovakia checked up their satellite in operation and when the time for an independent flight came, Magion separated from the Intercosmos carrier.

Its name can be easily deciphered. Together with its "elder brother" it investigated the magnetosphere and ionosphere of the Earth. The first syllables have composed the name of the vehicle. Being at some distance from each other, the satellites could better analyse the interaction of the magnetic environment of our planet and charged particles in the upper atmosphere. This was the principal aim pursued by the joint launch.

The joint space effort yields important practical results. It helps the researchers of different countries to see the necessity to work together, breeds the feeling of mutual respect, and thus serves as a vivid example of what relations should exist among the nations.

Man Explores the Moon

The drive to explore the Moon was started soon after Sputnik, the first man-made Earth satellite was launched. In 1959 the Soviet probe Luna 1 was sent moonwards. It was the first vehicle that overcame the Earth's gravitation, and at the escape velocity shot out into outer space. Having passed by the Moon at the distance of

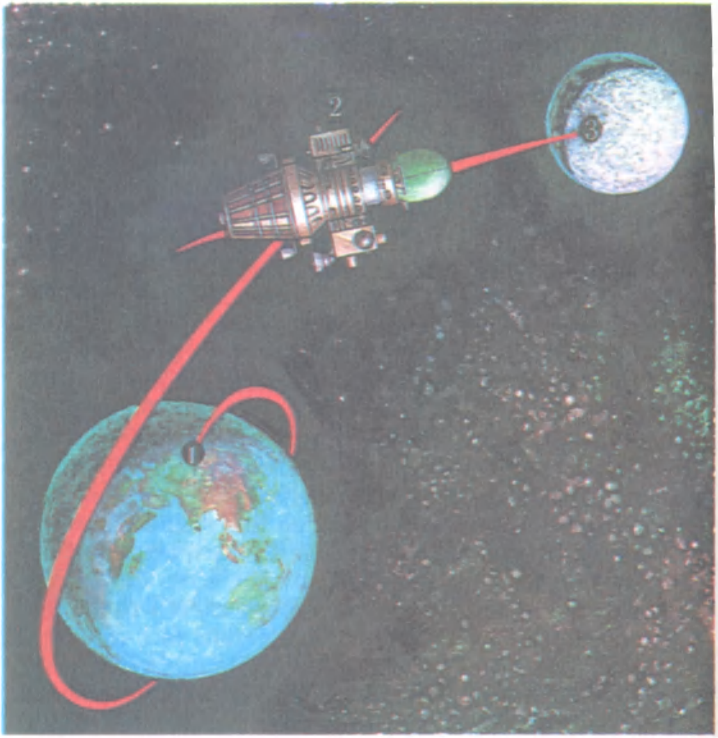
6,000 kilometres, the probe left the "sphere of influence" of the Earth and became the first artificial planet of the solar system.

Not more than a year later a new Soviet space vehicle set its course towards the Moon. It delivered to the surface of our eternal satellite a pennant with the image of the State Emblem of the USSR. Besides, the second Luna probe initiated the scientific study of the Moon by spacecraft means. Thus, it proved, that the Moon did not have any marked magnetic field.

In less than a month after the Luna 2 flight, the third vehicle had already been approaching the Moon. It was a space photographer. The Luna 3 probe, having circled the Moon, took pictures of its far side and made it visible to man for the first time.

The first probes were placed in a translunar trajectory right from the Earth. There were no trajectory corrections during the flight. It was necessary to keep the scheduled time of launching accurate up to a split second and maintain most meticulously the ignition sequence and firing duration for all stages of the rocket, so as the vehicle velocity and flight direction correspond exactly to the calculated values by the time of the engine shut-off. Any minutest deviation of these values from the given ones could have led to a gross miss during the flight towards such a remote target as the Moon. Besides, when the vehicle started for the Moon directly from the Earth, far from the most fuel-saving trajectories had to be chosen.

Hence, all the succeeding Soviet probes began their flight to the Moon according to a different scheme. At first, a powerful rocket delivered the probe together with a boosting rocket pod, or to put it simply, with a smaller space rocket, into a satellites's orbit; then at the appointed time the next start took place and the probe entered the translunar trajectory. If the trajectory was different from the calculated one, the correcting engine



The flight diagram of Luna 9:
1 – take-off; *2* – trajectory correction; *3* – moon landing

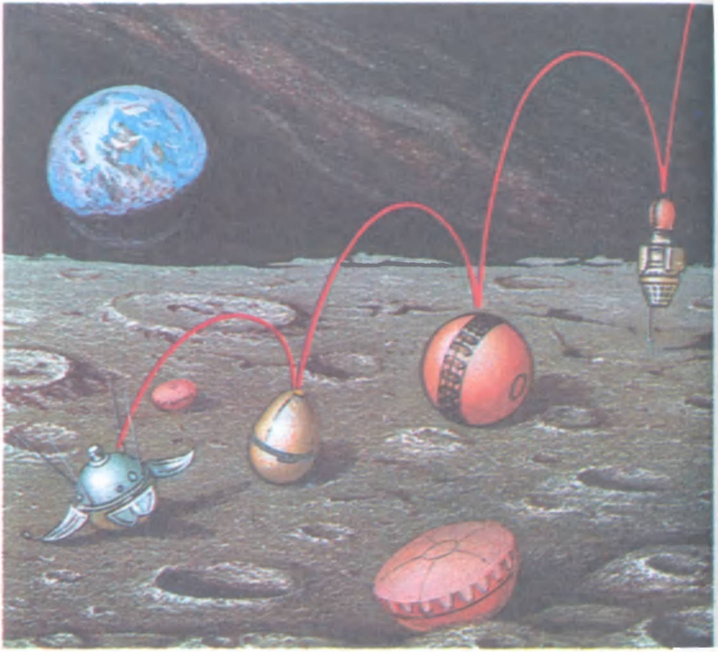
rendered its help. The success of the first flights proved that the task next in turn – soft landing on the Moon – was timely and quite attainable. During the flights that followed, the method, equipment and control system of soft landing were being developed.

The Luna 9 probe

Then came the 3rd of February 1966. On that day a space vehicle from the Earth had not merely reached the Moon's surface, but touched down soft on Ocean of Storms. It was the Soviet unmanned spacecraft Luna 9.

When several thousand kilometres separated the spacecraft from the Moon, it was orientated in such a way that the nozzle of its braking engine was directed towards the centre of the Moon. At the altitude of 75 kilometres the engine was ignited and its fiery jets, streaming toward the Moon's surface, softened the touch-down.

Luna 9 carried a special landing vehicle, an *automatic lunar probe*. During the braking, its elastic envelope was filled with gas and became a big elastic sphere. Attenuating the impact upon the lunar surface, the envelope split into halves and released the probe. The probe, having quivered without moving from its place, found itself in a stable working position. The upper part of its body opened, thus forming four petals of an antenna. The whip



Luna 9 landing on the Moon: probe separation, touch-down, impact attenuator fall-away, probe in operating configuration

antennas straightened up as if some exotic flower bloomed on a totally barren grey surface.

The television camera installed on the probe started shooting a first panorama of the moonscape. On the following morning, the picture was featured on the front pages of newspapers all over the world. People first saw the Moon as if they themselves had been on it.

Luna 9 told us of only one small part of the Moon's

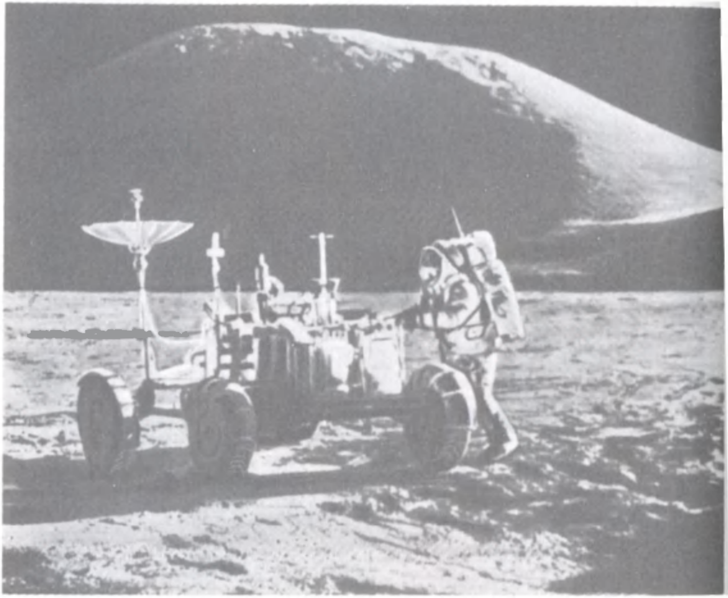
surface. So as to have a clear idea of the whole Moon it was necessary to watch it at a closer distance for a long while. This could be only done by an artificial lunar satellite, and the Soviet probe Luna 10 became it for the first time. The scientific equipment installed on it carried out a wide-scale lunar research. But detailed information concerning the moon rock could only be obtained through direct measurements made by special instruments.

The landing vehicle of Luna 13 soft-landed on the Moon in December 1966. Side by side with the antenna petals two one-and-a-half-metre-long "arms" put down on the lunar surface a sample-taker/penetrometer along with a radioactive densimeter. The *penetrometer* determined the hardness of the moon soil using a small powder rocket to force a metal cone into the soil. Movement of the cone was transformed into electric current and transmitted to the Earth by radio.

The density of the moon soil was measured by means of radioactive materials. The densimeter contained a source of radioactive radiation and charged-particle counters. A part of the radiation was absorbed by the soil itself, while the other, after multiple scattering, returned and was registered by the counters. The quantity of the particles returned depended on the soil density.

Several months after the Luna 13 mission, the lunar surface was troubled by a scoop of a miniature excavating machine installed on the American vehicle Surveyor 3. Not only dug the tiny scoop trenches in the moon soil, but also assiduously broke down lumps extracted by itself from small depth.

The flights of the Soviet and American probes to the Moon continued. The lunar probes imparted a sufficient amount of important information about the cover of the Moon. It was discovered that it is composed of rocks resembling slumped sand. We stopped minding the lunar dust and assured that the Moon's surface was quite firm



The American astronaut James Irwin beside his lunar roving vehicle on the Moon

to bear heavy vehicles. It would by no means be paltering with the truth to state that the automatic probes paved Man's way to the Moon.

The first who saw the Moon in proximity during their flight were the American astronauts F. Borman, J. Lovell, and W. Anders in laté 1968. One more test flight to the Moon followed suit. The astronauts were T. Stafford, J. Young, and E. Cernan. In July 1969 the rocket Saturn V with the spacecraft Apollo 11 were launched at Cape Canaveral. The crew members were N. Armstrong, M. Collins, and E. Aldrin.

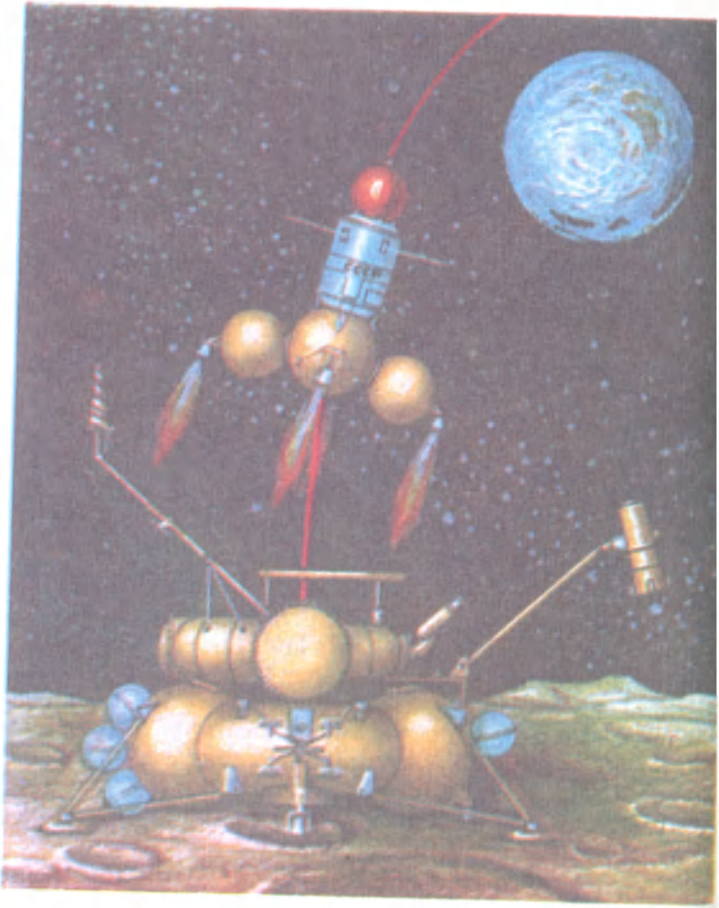
Apollo consisted of three parts: the command module, service module, and lunar module. In this space "train" the service module functioned as a "locomotive". It accommodated an engine, doing the work of both an accelerator and a brake. The lunar module was meant to serve the astronauts for landing on the Moon and return to a selenocentric orbit. The octahedral pedestal was supported by four spindle-like legs. The pedestal carried a contrivance which has a remote resemblance to Man's head. The hatch looked like the mouth, and the triangular windows seem as though they were a pair of eyes.

On taking up a near-moon orbit and manoeuvring in it, the lunar module with Armstrong and Aldrin separated from the spacecraft and started descending. Apollo 11, piloted by Collins, continued its flight around the Moon.

Having successfully landed on the Moon, the astronauts began their preparations to leave the cabin. On the 21st of July 1969 at 05 hours 56 minutes Neil Armstrong stepped onto the Moon's surface. A little later he was joined by Edwin Aldrin. The crew installed on the Moon instruments for scientific research and collected samples of the soil. Several hours later the ascent stage of the lunar module separated from the descent stage and entered an orbit around the Moon. After the docking with the command module and the astronauts' transfer into it, the ascent stage separated and remained in orbit, while Apollo 11 left a selenocentric orbit and went back to the Earth. On the 24th of July the re-entry vehicle of Apollo 11 managed a successful splash-down in the Pacific. That was how Man's first flight to the Moon ended.

The next spacecraft to follow the path opened up by the first crew of the Moon-travellers was Apollo 12. The astronauts Ch. Conrad, R. Gordon, and A. Bean brought one more load of the moon soil.

The flight of Apollo 13 reminded all that the paths in



The Luna 16 recovery vehicle starting back to Earth from the lunar lander

space were not devoid of unexpectedness and danger. An oxygen-tank explosion forced the mission's return home prematurely. Instead of landing on the Moon, Apollo 13 circled it and safely arrived to the Earth.

After that the crews of four more Apollos visited the Moon. During the latest expeditions the spacemen not only walked on the surface of the Moon, but drove upon it in an electric roving vehicle. The American programme of studying the Moon by means of manned spacecraft came to an end with the flight of Apollo 17.

In September 1970 the Soviet probe Luna 16 was launched. Just as its predecessors it was to soft-land on the surface of our natural satellite and then return to the Earth–a feat hitherto unaccomplished by any other automatic vehicle before. That was the reason why besides a landing stage the spacecraft also had a special Moon-Earth rocket.

In appearance it resembled a scaled-down Vostok, the spaceship of first cosmonauts. The recovery vehicles of both were ball-shaped, with the difference that one contained cosmonaut's seat and the other, a container for samples of the moon soil. In both cases the recovery vehicle was provided with parachutes and direction finders to facilitate the search of the vehicle. In both Vostok and the Moon-Earth rocket the instrument compartment was followed by the engine compartment. The Moon-landing stage served as a launching pad for the Moon-Earth rocket. The probe was to bring from the surface of the Moon a valuable load, and was to this end provided with a soil-collecting contrivance.

The probe landed on Sea of Fertility. By a command from the Earth the hold-down lock opened to release the drilling mechanism, and the electric motors lowered it onto the lunar surface. The core drill began to rotate, penetrated into the soil and was filled with it. The rod made complex manipulations again, but in the opposite

sequence. Then the drill with the soil entered the container of the vehicle. One more command, the drill separated from the mechanism and remained in the container.

And now – homewards! The final check-out of the rocket is over, and the lift-off takes place exactly at the appointed time. The dazzling flash illumines the landing gear, that will always remain on the Moon. The Moon-Earth rocket, picking up speed, shoots out towards the Earth. After three days of flight the recovery vehicle separated from the rocket and entered the Earth's atmosphere.

The moon soil is on the Earth! But what had seemed to be a miracle the other day, did not satisfy the scientists any longer. Having ascertained the rock composition of the lunar "sea" surface, they became interested in the composition of the lunar continents. It didn't take long for the Luna 20 probe to set out on a geological expedition to the lunar mountains. The mission was successful, in spite of the arduous landing conditions, and soon the scientists were able to place tiny bits of the lunar continent under their microscope. Not more than five years had elapsed before the laboratories on the Earth were enriched by one more sample of the moon rock; this time from the "coasts" of Sea of Crises. The sample had a particular value, because the Luna 24 probe took the rock not from the surface, but from a depth of about 2 metres.

If we look at the lunar globe installed in the Mission Control Centre, we shall see little red stars on it. They show the points where the Soviet probes landed. What immediately catches the eye are three points situated close to one another. This is where the automatic geologists, Luna 16, Luna 20, and Luna 24, landed on the Moon. Their neighbourhood is not accidental. The line that passes through the three points connects, so to speak, the three epochs in the history of our eternal satellite.

The most ancient lunar rocks were brought by Luna 20, which landed on the continental isthmus between two seas. The lava that had filled one of them, Sea of Fertility, is comparatively younger. The lava samples were brought by Luna 16. Sea of Crises, where Luna 24 touched down, is quite "young" according to the geological time-scale. The fall of the gigantic meteorite dug out its round bowl "only" some 2.5-3 milliard years ago. Thus, the scientists received three samples of the moon soil, representing a sequence of several stages in the evolution of the Moon.

However, each sample in itself is also fairly representative. There can hardly be any doubt that a tiniest particle of regolith, which is a loose rock covering the Moon, has been transferred throughout millions of years from one place to another, and countless times too, by meteoric impacts upon the Moon. Hence, only a pinch of soil can say quite a lot about the structure of thousands of kilometres of the Moons' surface.

The history of the Moon is imprinted in the sequence of constituent layers. A drill core of the moon rock is a kind of annals featuring events of the Moon's life. Its "pages" are represented by different layers, and it was this representative core of moon soil that Luna 24 brought back to the Earth.

The roving vehicles of all imaginable constructions had already been crossing lunar seas for some time. They had been negotiating fissures and climbing up steep walls of craters. But the Moon for them was here – on the Earth. It is, indeed, difficult to simulate the harsh lunar conditions. Nevertheless, those who had planned the lunar testing grounds made every effort to build craters, fissures, heaps of boulders and rugged hillsides.

Metal caterpillars, plastic spheres, spiral propulsors, resembling fantastic worms, and clumsy wading "legs" – were by far not the only running gear for the lunar rovers. The good old wheel also found itself among the devices

under test. Quite unexpectedly it has proved to have no rivals in reliability.

And now the wheels of Lunokhod, the first lunar "rover", laid down tracks on Sea of Showers. It was delivered there by the Soviet Luna 17 vehicle. At first sight, Lunokhod 1 seemed disproportional. Its wheels seemed undersized and rather fragile though they carried a big heavy tank, an instrument container. And it was only on second thoughts that one realized that on the Moon everything weighs six times less than on the Earth.

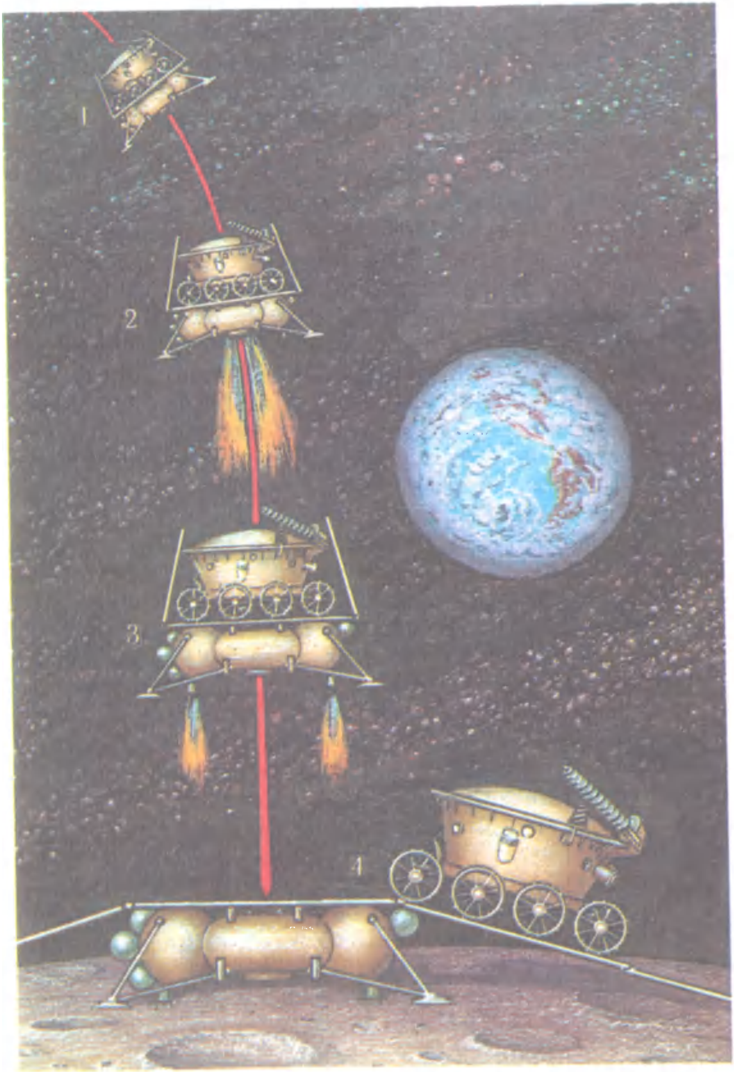
Each wheel of Lunokhod was driven by its own electric motor and had its own brake. The question may well be raised: why electric motors? The answer is simple: because it is the only motor that can get fuel on the Moon. We mean solar energy supplied unsparingly by the Sun. On the underside of the lid of the instrument container the solar cells were attached. The lid could be swung at any angle, even 180 degrees. Thus, the strength of current could be regulated, charging the chemical sources of power supply.

Lunokhod could not only move forward and backward, it could also turn round. The wheels on one side of the vehicle were rotating, while on the other side they were being braked. This ensured a high manoeuvrability. The vehicle did not rush headlong into any crater and made no attempt at climbing up impassable hills. When the approved angle of inclination was exceeded, it stopped automatically.

Space vacuum called for the instrument container to be sealed; a sharp change in temperature, from +130 °C by day to −170 °C at night, necessitated a complex system

The Luna 21 probe landing on the Moon:

1 – approach for landing; *2* – brake engine firing; *3* – soft-landing engine firing; *4* – Lunokhod 2 rover leaving the lunar lander


1
2
3
4

of thermoregulation. During the lunar day, this system removed heat from the equipment inside the container and heated the gas filling at night.

The eyes of Lunokhod were television cameras. Watching the terrain, they conveyed everything that came into their vision to the members of the crew. The working places of the commander, navigator, driver, and vehicle engineer were at a distance of hundreds of thousands of kilometres away from their vehicle – at the control consoles of the distant-space communication centre. From there the crew controlled the vehicle by radio. It was by no means simple. Within the time during which the radio signal reached the Moon and the feedback signal returned, Lunokhod managed to cover several metres.

The surrounding terrain did not abound in marked reference points. Nevertheless, the crew drove the vehicle strictly in accordance with the planned route. Thus, after a lengthy traverse of Sea of Showers, the vehicle was driven back exactly to the place of landing of Luna 17 but by a new route. What, then, were the instruments that helped the navigator hold the vehicle's course?

On the Moon the magnetic needle of a compass is absolutely useless. The Moon does not have any magnetic field of its own. But it is hard to lose one's bearings there should one follow the stars, the Sun... and the Earth. The lunar sky is free of clouds which hamper terrestrial observations of the celestial bodies. For the purposes of astronomical navigation, Lunokhod 1 was provided with two television cameras, or *astronomical telephotometres*. With their help Lunokhod saw the Sun and the Earth. The images sent back to the distant-space communication centre showed the brightest heavenly bodies in the lunar sky and thus helped the navigator take bearings and determine the direction of movement.

The turning angle of the self-propelled vehicle was determined with the aid of a directional gyroscope. When

the vehicle turned, the gyroscope axis remained in the initial position, while the case of the instrument moved in respect to the axis.

The distance covered by the self-propelled laboratory was calculated by the number of revolutions made by the wheels, each of which had a special sensor attached to it. If on some part of the route the vehicle slipped, the calculations were corrected. The correction was determined by the revolutions of the freely rolling, never slipping, ninth wheel. The crew was informed of various inclinations by one more gyroscope sensor, the so-called *gyroscopic vertical*.

The lunar rover sported a wide scope of specialized skills. It sent back to the Earth scores of panoramas of the surrounding terrain. The instruments installed on its body systematically determined the strength, density and chemical composition of the moon rocks. The plate treated with radioactive isotopes irradiated the soil next to the vehicle, and every single chemical element responsed to irradiation in its own way.

The Lunokhod vehicle was equipped with a *laser reflector*. The distance from the Earth to the Moon was measured using the time that elapsed from sending the laser beam from the Earth to reception of a reflected beam.

Astrophysics was also within the scope of Lunokhod's investigation. Sensors of the X-ray telescope installed on it were directed straight into the zenith.

The lunar expedition of the first automatic self-propelled laboratory lasted nearly a year. It was a time sufficient for the scientists to discover quite a lot of new things about the Moon. The designers of the vehicle had acquired substantial experience in operating the first model of an extraterrestrial vehicle. The way engineers made use of the results became quite obvious when, in the beginning of 1972 on Sea of Serenity the first tracks of

Lunokhod 2 were made. It was delivered to the Moon by the Luna 21 spacecraft.

The new Lunokhod's "eyesight" improved. The designers increased its visibility by raising one of the television cameras. Frames on the driver's TV screen began to change more often. The movement became more visualized, more perceptible, as if the driver and the "road" 400,000 kilometres away were on the opposite sides of the screen. The new Lunokhod had a greater velocity. It could turn in motion and was more quickwitted in obeying the commands.

As compared with its predecessor, Lunokhod 2 not only explored the sea surface, but reached the lunar mountains. Alterations and improvements introduced into its scientific equipment also widened the scope of its applicability.

We know far from all about the Earth's natural satellite. But... just as every great geographical discovery was always followed by the settlement of the new lands, so will the exploration of the Moon inevitably lead to the use of its riches for the benefit of people.

Mars Receives Guests

Quite recently all we knew about the planet Mars was based on astronomical observations only. Then space technology has come into action.

The first space vehicle to be launched towards Mars was the Soviet Mars 1 probe. In 1962 this vehicle broke a record of long-distance space radio communication. But... it failed to reach its goal.

At the close of the sixties the American vehicles Mariner 4, Mariner 6, and Mariner 7 flied by Mars and took close-up pictures of it. However, the vehicles were near the planet for too short a time to obtain any detailed information.

As had been most convincingly proved by the example of the Earth, the "global" research of a planet yielded more tangible results if it were conducted from orbits of its artificial satellites. Mars acquired them too. In 1971 the American vehicle Mariner 9 and the Soviet automatic probes Mars 2 and Mars 3 were put in planet's orbits.

When Mars 2 was approaching the planet, a capsule was ejected from the vehicle. It brought onto the surface of Mars the pennant with the State Emblem of the USSR. The vehicle itself took up a satellite's orbit. What has just been said implies a whole gamut of highly complex operations that were performed by the robot at a distance of hundreds of millions of kilometres from the Earth. Let us go back to the time when Mars 3 made its flight, and try to retrace the sequence of events that had taken place.

When the planet and the space vehicle were separated by only 70,000 kilometres, the final correction of trajectory began. Incidentally, all operations were performed by the vehicle independently, without any prompting from the Earth (just as was the case with Mars 2). The bowl of the vehicle-borne transmitting antenna had to be directed towards the Earth, in order to maintain communication. The reference points here were the Sun and the star Canopus. The microjets turned the vehicle into a position in which each of the heavenly bodies got into its "own" sensor. Now, the antenna was most accurately directed to the Earth. The position of the vehicle thus acquired was maintained with the help of the microengines of stabilization.

What the navigation system had to do next was to determine the distance to Mars and the direction to the centre of the planet's disk. It is not difficult to measure the distance to a remote object, if we know its true dimensions. The diameter of Mars has been known to us for a long time. When the probe was still far away, the planet seemed to its "eyes" a small round blur. The nearer the

station got to Mars, the bigger the blur became. Soon the silvery disk covered the whole field of vision of a special optical instrument, which meant that there remained only the preset distance to Mars. The probe's "sense organs" conveyed the information gathered to its "brain" – the on-board computer.

Calculations followed. Upon correction, the vehicle was to go into a trajectory 1500 kilometres distant from the planet's surface. Taking this into account, the computer determined where the engine's nozzle was to be directed, and commanded the microengines of orientation to turn the station accordingly. At the same time the brain gave instructions to the timing device when and for how long it should cut in the main engine. At a given moment the gas jet emitted from the nozzle shifted the vehicle into a new trajectory. The Sun and Canopus "prompted" the vehicle what position it should acquire so that its antenna could be turned towards the Earth again.

The correction session lasted more than an hour. All that time the communication with the probe was discontinued. The Earth did not hear its signals the moment the transmitter began to operate. It took the radio signal from Mars 8 minutes to reach the reception antennas of the distant-space communication centre. That was particularly the reason why the control of the vehicle at the concluding stage of the interplanetary flight was "handed over" to the vehicle itself.

Right after the trajectory correction, a lander separated from Mars 3. For some time they were flying side by side. Then, the lander's engine made the course change over to a transmartian trajectory. Four and a half hours later, the lander's nose cone touched the gaseous envelope of the planet.

The Mars' atmosphere is very rarefied. In its upper layers the density is practically inconsiderable. Hence, in

spite of a tremendous velocity, the lander did not encounter any resistance for some time. However, the closer it came to the surface, the denser the atmosphere became, and the greater its drag on the nose cone. Soon the atmospheric drag slowed down the descending lander, and the overloadings began to decrease. By a command of the overload sensor, the powder rocket extracted an auxiliary parachute. A small canopy drew a big one. The descent velocity decreased, but still exceeded the velocity of sound. Having accomplished its task, the auxiliary parachute separated from the main one, and a small jet engine put it aside. The main parachute deployed with some delay, which saved it from being torn asunder by the dynamic pressure of the Martian "air".

The movement of the lander became still slower, and the timing device allowed the main parachute to deploy fully. The protective cone separated and fell down. The lander unfolded antennas of the radio altimeter to ensure soft landing.

The surface of the planet was getting nearer. When it was at a distance of not more than 30 metres, another jet engine put aside the main parachute so that the lander would not find itself covered with its huge canopy.

At the same time the timing device ignited the soft-landing engines. The last braking. Having fired for a scheduled time, the engine was jettisoned. A fraction of a second... and the lander touched down on the surface of Mars. The timing device continued to work. By its command the man-made spacecraft sent a message from the Red Planet–for the first time in human history.

Those who constructed the Martian lander were aware of dust storms occurring on Mars. That was why they had done their best to protect the vehicle from dust. But they were certainly unable to forecast an unprecedented storm that would be raging on the planet in September and for many months to come would cover entire

Mars with a dust veil. It was as though Mars had all of a sudden recalled the belligerent deity that had conferred its name upon it. The wind velocity at the surface reached that of a tornado. This might have accounted for such a quick black-out of transmission from Mars.

Where was then the interplanetary probe Mars 3? Having parted from the lander, that could well be called its passenger, it was approaching Mars. However, its path lay aside. Preparation for the braking began. Once again the computer turned the vehicle and ignited the engine at a required time. Having rounded the planet, Mars 3 became its new satellite.

When the probe was flying over the touch-down place of its lander, it heard the lander's "voice". It was too feeble to cover the enormous distance between the two planets. Powerful transmitters of the probe relayed it to the Earth.

The scientists have provided Mars 2 and Mars 3 with a host of research skills. The Martian satellites were supplied with scientific instruments. Some of them painted a "thermal portrait" of Mars, a chart showing the temperature distribution at its surface. Others defined more exactly the composition and the density of its atmosphere. There were also those that gave a detailed description of the planet's relief.

The satellites were equipped with different photographic cameras. Some of them photographed vast areas of the surface, while others shot close-up pictures. The probes photographed Mars at various distances and using different light filters. The film was developed on board the stations, and then the pictures were conveyed to the Earth by means of television cameras.

The pictures have discovered Mars anew. Gigantic volcanoes were stupendous. (The largest of them, Olympus Mons, is about 20 kilometres high and nearly 600 kilometres across its base.) Striking were huge fissures, compared with which, the Grand Canyon in Ari-

zona seemed no more than a scratch. There were vast deserts with surfaces as flat as a board.

But what took the planetologists' breath away was not this. Their attention was drawn to the odd long furrows tortuously spreading among the hills and mountains. No, the famous Martian canals created by optical illusion had nothing to do with it. The strange surface details reminded most of all of... the beds of dried-up rivers. Rivers on Mars?! On a planet with such thin atmosphere that even the liquid water must inevitably boil and evaporate? However, the fact remains, the beds were there; so were the huge ravines that looked very much like the ones we have here on the Earth.

In the summer of 1973, four Soviet probes were directed to Mars at once. Mars 4 and Mars 5 reached the neighbourhood of the planet in 1974. First, Mars 4 flied by the planet at a distance of 2200 kilometres and transmitted to the Earth the photos it had taken; then, two days later, Mars 5 entered a Martian orbit.

Mars 5 redetermined the quantity of water vapour in the atmosphere. That time, there was more of it than what had previously been detected by the first satellites, but too little all the same. It was insufficient to form any body of water. The observed data did not throw any light on the problem of Martian rivers. There came a time for hypotheses. One of them, most incredible at first sight, became popular with a great many. Its adherents asserted that the climate on Mars could change regularly within the period of several millions or even hundreds of thousands of years. According to the proponents of the said hypothesis, Mars was, so to speak, on the swings of evolution. Hence, a comparatively short time ago, Mars could have water at its surface, and also the atmosphere, the density of which was similar to what we have on the Earth. Then, as a result of the change in climate, the atmosphere was frozen and took the form of polar caps.

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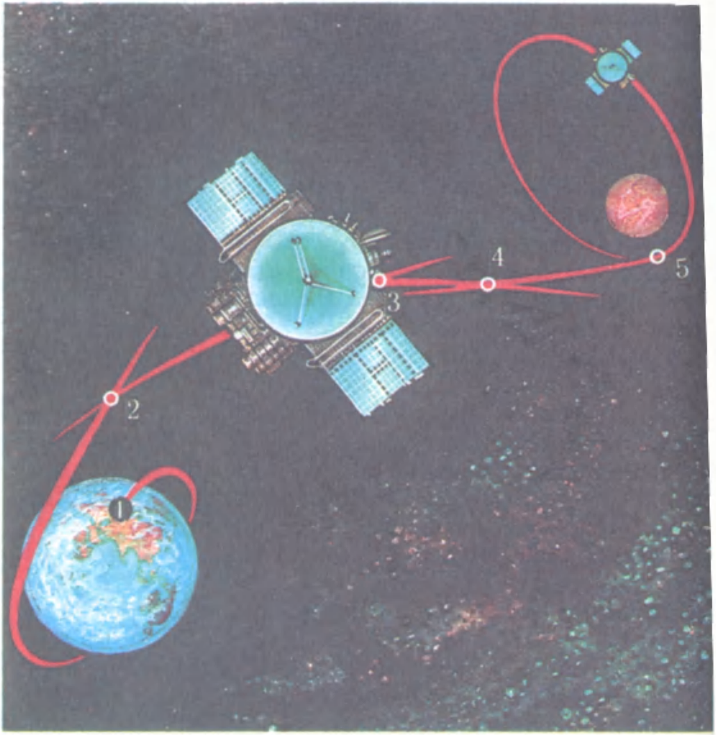


The flight diagram of the Mars 5 probe:

1 – take-off; *2-4* – trajectory correction; *5* – braking to enter an orbit of artificial Mars satellite

Mars 5 had been already working in orbit for a month, when the next envoy of the Earth approached the planet. The lander of the Mars 6 probe soft-landed on the planet's surface. Before the touch-down, descending by a parachute, the lander became the first to examine the

planet's atmosphere from within. At that time American specialists said that the USA would not be able to achieve a soft-landing on Mars like that of the Soviet lander before 1976. And the predicted time came. A pair of American spacecraft, Viking I and Viking II landed on Mars.

In its time Mariner 9 sent back to the Earth photographs showing the surface of Mars. They seemed to indicate a fairly good landing ground for Viking I. But when its TV "eye" surveyed the selected area, it caught sight of craters, fissures in lava, and heaps of rocks. Traces of former water courses, such as "hollows" and "islands", were not more encouraging. It was agreed that landing should be postponed. In fact, it had to be put off once again. To find an "airfield" on the planet turned out to be quite a problem. The astronomers gave a hand. Scanning Mars with the beam of a radio telescope, they discovered a level spot in Chryse Planitia suitable for the purpose. It was the place where a lander of Viking I arrived. Its landing report was expected for 20 minutes. It was the time that took radio waves to cover the distance of 340 million kilometres, then separating Mars from the Earth.

The cloud cover of Venus, the rings of Saturn, and the Great Red Spot of Jupiter are the distinguishing features of these planets of the solar system. Mars differs from its space neighbours in its colour. However, one hardly expected the planet to be so red in colour, but the photograph showing it all in crimson is conclusive. One perceives the slightly ruffled plain densely covered with scattered stones as if through a transparent red fragment of glass. Over the red desert there hangs a sky of delicate pink which gains more and more light from the bottom upwards. The wind has subsided, leaving behind each stone a smooth hillock of pink dust and baring the reddish spots of a flat cliff. The remote and inconceivable

world is redolent of the crepuscular calm on the Earth. And thin nebulous haze covers the morning horizon.

An arm extended from the lander and scooped up a shovelful of orange-red stones that seemed to be covered with scale. The trace left by the shovel was reminiscent of the Moon. Both there and here the edges of an excavation were sharp, while the walls did not crumble and remained vertical like in wet sand.

The Martian soil contained a large amount of iron (approximately 15 per cent). Besides, the Viking's X-ray spectrometer discovered a considerable quantity of silicon, calcium, phosphorus, and aluminium. The presence of rubidium, strontium, zirconium, and potassium was also noticeable. Next to Venus, Mars has produced one more proof testifying to the affinity among the planets belonging to the terrestrial group. For instance, a major part of the stones turned out to be fragments of basalt lava. Doesn't it mean that here, just as on the Earth and the Moon, volcanoes had been active in the distant past?

But the sum and substance of exploring the Mars' surface consisted in detecting life.

The terrestrial microorganisms, absorbing nutrients in the process of their life activity, excrete various gases. Consequently, it would be logical to assume that the unknown Martian bacteria act accordingly. The would-be inhabitants on the planet were offered food flavoured with special "spices"–a nutrient solution containing tagged atoms of carbon. If the Martian bacteria actually assimilated carbon in the likewise manner as their terrestrial counterparts, the radioactive isotope would be found in the gases excreted by them.

The first news from Mars was encouraging and perplexing at the same time. The Mars-based counter clicked far more frequently than the instrument in a terrestrial laboratory, where a control experiment was carried out with genuine microorganisms. One of the supervisors of

the biological project said that the information received from Mars could be interpreted in favour of the possibility of life over there. But, first and foremost, all other explanations had to be ruled out.

What caused even more agitation were the readings of another instrument intended to examine the gas exchange of the sought organisms with the environment. The soil contained in the planet's atmosphere was soaked in nutrient broth and warmed up. At regular intervals samples of the "air" were taken for analysis. Quite soon (two days later, instead of twelve as had been previously estimated) the evolution of oxygen was registered which was 15-20 times greater than what had been anticipated. The research supervisor of the Viking Project did not conceal his perplexity when he said that on their part it would be too far-fetched to say that they knew what those findings meant.

The reaction of the dry soil with the liquid could be violent indeed. However, it was tempting to suggest biological causes too. Conjectures, rather risky at times, presented themselves instantly: "Taking into consideration the rigorous conditions on Mars (the temperature at the place of landing varies between -85°C and -30°C), it cannot be wholly discarded that the living organisms there remain in a state of 'sleep' and require particular conditions to be brought back to active life. A sumptuous quantity of water and nutrients would actually be a feast for the microorganisms".

The evolution of gases in both instruments took more time than is usual for chemical reactions, but less time than required in biological processes. "We are somewhere in-between", was what one of the scientists said.

On the Earth the chlorophyll-containing cells form, under the action of sunlight, organic substances from carbon dioxide and water. Doesn't the Martian life make use of the solar energy in the same way? Into the Martian

"air", which filled a vessel with the soil, a little quantity of a radioactive isotope of carbon was introduced. In order that the microbes, if any, felt at home, a lamp was lit above to simulate the sunlight typical of Mars. The incubation lasted several days. The cells were given every opportunity to assimilate the tagged carbon. Then, gases were removed from the chamber, and the soil was heated to 600°C. The procedure involved the volatilization of organic substances formed in the process of photosynthesis, while the counter of radioactive particles was to estimate the quantity of tagged atoms in the gas. The course of the experiment also threw the scientists into confusion. The level of radioactivity registered was six times greater than the one observed in the case when the soil was totally devoid of microorganisms. But the experimenter asserted the following: "We have not discovered life on Mars, since the explanation of the use of carbon by something contained in the soil samples lends itself to a considerable number of interpretations".

To solve the problem of whether the "something" is a living thing or not was destined to become the purpose of the check experiments. New samples of the soil were placed into the devices intended to discover metabolism and photosynthesis. They underwent sterilization by prolonged heating. Under those conditions, the microorganisms, if any, were to be destroyed. It was quite natural, then, that the products of their activity could hardly be manifested.

Everything agreed with what the biologists had been expecting. "If we had witnessed these results in some laboratory", said one of the researchers, "we should have inferred that a feeble signal, though undeniably of biological nature, had actually been received". But he added, "Since the signal comes from Mars, we should be extra cautious". Another specialist involved in the research said, "As a result of the check experiment, the

opinion on the biogenic nature of carbon dioxide received equal rights with the opinion concerning its chemical nature. However, it is far too premature to provide any categoric statement".

The terrestrial forms of life, such as cells and primitive organisms, consist of substances that are built on the basis of carbon. Their exploration had also been one of the tasks set before the automatic biological laboratories. "If life consisted of words and sentences, then the experiment initiated by the mini-laboratory of Viking represents the quests for letters. An organic analysis of the Martian soil can reveal letters, i.e. the organic molecules testifying the presence of life on the Red Planet either in the past or now", wrote the American papers.

Search of extraterrestrial life on the molecular level have been conducted for a long time. Traces of organic matter have more than once been found in meteorites; even among interstellar molecules we can find complex compounds of carbon. On Mars the organic matter could have appeared as a result of chemical processes; it could have been brought there by meteorites, and, finally, it could not have been dispensed with either by the life long vanished, or by the life that still goes on.

In short, no organic substances have been found on Mars. This result discouraged the biologists. But they did not lose hope and were expecting the landing of Viking II. It touched down on Mars at a distance of several thousand kilometres from the landing place of its predecessor, on the opposite side of the planet.

From the satellite's orbit the region of Utopia seemed markedly different from the place where the first vehicle landed. But, what surprised everyone was that a familiar panorama lay before the "eyes" of the Viking lander. As in the very first photographs, it was the same red plain devoid of any features of life, with the same abundance of stones, the same pink dust, and above all that hung the

same crimson sky. If two pictures were placed side by side, an "old" one and a newly received from Mars, not everyone would be able to tell one from the other. But still more striking was the similarity of data provided by the research equipment.

Well, is there life on Mars or not? The supervisors of the Viking Project gave the following answer to this question: "We don't know whether there is any life on Mars, but we think that there is no evidence that would make it imperative for us to exclude this possibility". The eminent astrobiologist Professor C. Sagan expressed his opinion more precisely. He says that the greatest forms of life can be so unusual and odd in their shape, chemical composition, and behaviour that it is impossible to identify them as life. The Viking experiments may yield negative results, but at the same time the Martian organisms can be savouring the zirconium paint from the vehicles that have landed on Mars.

What is of particular interest is that Vikings have opened up new vistas for hypotheses. C. Sagan, for instance, does not exclude the possibility that there may be isolated oasises of life on Mars. Great quantities of water discovered there may well serve to substantiate this supposition. One of the satellites reported that the northern polar cap of Mars was actually covered with a kilometer-thick layer of ordinary ice, but not with carbon dioxide, as was considered before.

Professor V. I. Moroz, a well-known Soviet planetologist, writes: "The kernel of the Viking scientific programme was three biological experiments, which were supposed to answer the most important question, whether there is life on Mars, but the result of the experiments perplexed those who were carrying it out. These experiments cannot be regarded as either the positive or the negative answer". However, giving due credit to the American researchers, the Soviet scientist highly appre-

ciated the new significant data on the condition of the atmosphere, its vertical structure, mechanical properties of the soil, and the geological characteristics of Mars regions.

Each flight of a space vehicle to the planets of the solar system stirs the turbulent wave of scientific disputes and discussions that have been taking place for quite some time. It was exactly the case after the missions to Mars. New interpretations of what was seen on the Red Planet have been advanced with time. For instance, in 1983 K. Ya. Kondratyev, Associate Member of the USSR Academy of Sciences, and his colleagues expressed their views on the Martian rivers. They considered it quite feasible that the rigour of the climate on Mars was alleviated by active volcanoes in the past, the stupendous size of which produced such a marked impression on the specialists.

It may be assumed that quite a few of us have heard of the so-called "greenhouse effect". It is the property of the atmosphere to let the solar radiation pass, retaining, at the same time, the thermal radiation of the heated surface directed back. This phenomenon is accompanied by the heating-up of the planet, and is typical of any planet that has an atmosphere, e. g. the Earth or Venus. On Mars, however, with its extremely thin atmosphere, the phenomenon is totally imperceptible.

The proponents of the hypothesis think that the greenhouse effect could have played a more prominent role on Mars. In their opinion, the process was as following. During the periods when the huge volcanoes resumed their activity, powerful streams of lava poured down to the surface of Mars, while the atmosphere was filled with a vast amount of ashes and water vapour. When cooled, the lava released gaseous sulphur dioxide, which, together with water vapours, formed a cloud cover over the whole planet. It consisted of tiny droplets

of sulphuric acid. The said cover enhanced the greenhouse effect, the temperature on the planet's surface began to rise, with the moisture content in the atmosphere increasing. This was followed by rain and snow that were responsible for the formation of watercourses which have left such marked traces. But when the activity of volcanoes subsided, sulphuric acid solutions suspended in the atmosphere gradually flowed onto the surface of Mars, enriching it with sulphuric compounds. Further examinations of the planet's soil composition proved that there was much more sulphur in it than, say, on the Earth.

S. I. Aksyonov of Moscow University made an attempt to recur to the problem of life on Mars. Casting doubts on the unpromising results of the previous studies, the scientist tried to at least partly account the phenomena that were brought to light in examining the Martian soil for the activity of hypothetical Martian microorganisms. To do this he had to form an assumption that the tiny "Martians" were distinctly different in nature from their terrestrial counterparts and that their interrelationship with the environment was built on totally dissimilar principles.

The idea propounded by Aksyonov met with objections on the part of Academician A. A. Imshenetsky, a well-known microbiologist, who, in his laboratory experiments, had once again proved that some inanimate components of the Martian soil could have imitated the lifelike processes in the analyzers of Vikings.

However, the scientists did not stop at that. In several years' time a group of Soviet researchers run new experiments. The composition of the Martian soil being basically known, the scientists were able to create its analogue consisting of various terrestrial rocks. The experimental conditions were made as close to reality as possible. An ampoule with the sample was calcinated in

such a way that not a trace of terrestrial microbes remained. The air was totally evacuated and the ampoule was filled with the Martian "air" – carbon dioxide. Then the sample was irradiated by high-speed electrons and gamma rays.

It is in the latter procedure that the main distinction between this and the previous experiments could be found. The scientists thought it was supposed to imitate the stream of cosmic rays continually bombarding almost unprotected Mars and gradually changing the chemical composition of its surface layer. The radiation dose selected for the purpose was equivalent to the energy brought to the surface of the planet by the particles from outer space within one and a half milliard years.

Into each handful of the Martian dust taken for analysis the automatic meter-mixers of Vikings added some water. It was exactly the same procedure that was performed by the experimentators with the preconceived dead artificial soil. In conducting the investigation they saw processes that reminded them of those that had previously been seen on Mars and were at first taken for the result of a biological activity.

Does it mean that the Red Planet should once and for all be regarded as lifeless? Or is there still some hope? Unfortunately, the quest for the confirmation of the hypothesis on the part of the Soviet scientists has as yet been far from optimistic.

The Destination Is Venus

The history of scientific study of Venus begins with two great names – Galileo and Lomonosov. In 1610 Galileo was the first to discover the phases of the planet. In 1761 Lomonosov proved that there was an atmosphere on it. For nearly two centuries after the Lomonosov's finding research had been conducted at a very slow pace. Then

came the twentieth century, and with it the scientific and technical revolution.

Radio waves sent to Venus and reflected by it back to the Earth helped to determine the direction of the planet's rotation and the duration of its astronomical day. The year on Venus consists only of two Venusian days each of which corresponds to 118 Earth's days. It has also been established that Venus does not have any seasonal changes.

Earth-based observations of the Venus' thermal radiation enabled the scientists to evaluate its temperature and chemical composition of the upper atmosphere above the permanent cloud cover. It has been discovered that its atmosphere contains carbon dioxide, though the researchers had assumed that its concentration was inconsiderable and that the gaseous envelope of the planet consisted mainly of nitrogen. By means of radio telescopes the Venus' own radioactivity was analysed. It was made clear that the surface of the planet is heated to a great extent, though in assessing the temperature no single opinion prevailed. The pressure has also remained uncertain.

Only four years since the beginning of the space age, a Soviet automatic probe was set off on its long journey to Venus. In 1965 two space vehicles were launched in the wake of the first probe. One of them, Venera 3, reached the planet, and the first interplanetary flight came to an end.

Only a year later, the experience thus gained made it possible for the Soviet designers and scientists to conduct a unique experiment in probing the Venusian atmosphere. The experiment was carried out by Venera 4. Its descent vehicle, on entering the atmosphere at the escape speed, continued descending by a parachute. The flight made it clear that the dense blanket of the Venusian atmosphere almost wholly consists of carbon dioxide.

For the first time measurements were taken to determine the temperature, pressure and density of the atmosphere.

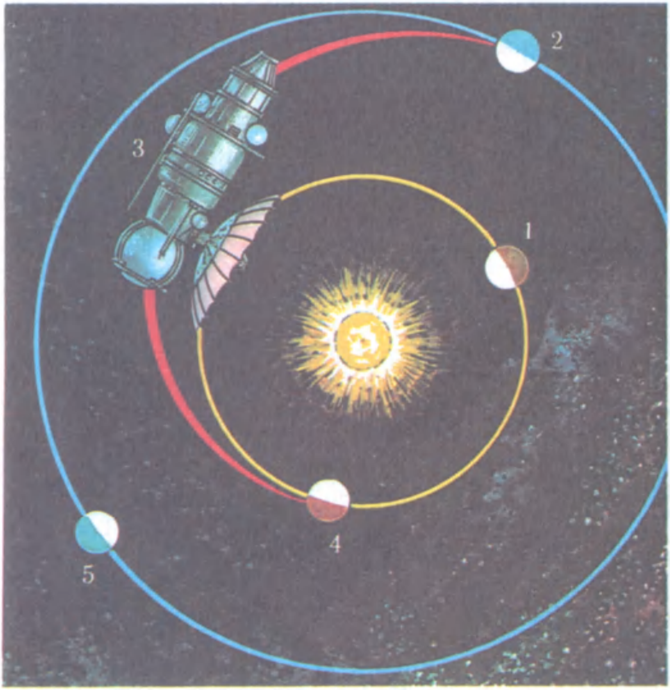
In 1969 two automatic vehicles, Venera 5 and Venera 6, at a time made a deep probing of the atmosphere in various regions of the planet. It was found that the atmosphere contained, besides carbon dioxide, inconsiderable quantities of nitrogen, water vapour and oxygen. The probes completed their investigations at the altitude of approximately 20 kilometres above the surface. The data gathered by them were in agreement with those obtained by Venera 4 and the American spacecraft Mariner 5, a "fly-by", which examined the atmosphere using radio inspection. When the vehicle was behind the planet, the characteristics of radio waves sent back to the Earth by its transmitter underwent substantial changes. That was accounted for the fact that when Venus and Mariner found themselves in such relative position, Mariner's signals had to pass through the atmospheric gases.

But the surface of Venus remained unattainable. Such was the state of things till 15 December 1970. On that day this unexplored alien landscape saw its first lander descending from the Soviet automatic vehicle Venera 7.

Just as the preceding spacecraft of this type, Venera 7 consisted of two main parts, an orbiter and a lander. The orbiter had the form of a large metal cylinder containing instruments to control the flight of the vehicle, radio receivers, transmitters, and other equipment. On the outer side of the vehicle there put up a large umbrella of the pencil-beam antenna to keep in touch with the Earth.

The orbiter contained a correcting engine owing to which the vehicle was accurately led out onto the target. The orbiter also had the lander attached to it. The orbiter-borne storage batteries supplied the vehicle with power. It was the function of the solar cells to restore the power supplies.

During almost the whole of the flight the vehicle was



The flight diagram of Venera 5: the position of Venus (*1*) and Earth (*2*) at the starting moment; the position of Earth (*5*) and Venus (*4*) during the final approach to Venus; trajectory correction (*3*)

orientated to the Sun. The optical sensors had the Sun and the Earth or the Sun and a specially selected star within the field of their vision. By commands of the sensors the automatic devices of the attitude control system cut in and off the gas-jet microengines.

The main function of the orbiter was to deliver the lander to the planet. In the preceding flights no problems had ever arisen in connection with the accomplishment of that function. That is why the main attention of the designers of the new spacecraft was wholly focused on the lander. Its shape resembled a huge egg. If we could split it apart, we would see its "yolk" – a spherical pressurized instrument compartment. On top of it there was a parachute compartment which also contained an antenna.

When the vehicle impacted with the atmosphere, the overloadings sharply increased and the weight of every single nut of every instrument became 300-350 times that on the Earth. The vehicle was confronted with a so-called shock wave. The temperature between the latter and the vehicle body almost immediately jumped up to 11,000 °C. It was the thick heat shield and the thermoregulating system that saved the vehicle. In the instrument compartment a normal operating temperature was maintained.

The atmosphere abruptly retarded the movement. Soon the canopy of a parachute opened out above the vehicle. This was followed by a smooth descent. The familiar height of 20 kilometres was behind. What lay ahead was yet unknown. The temperature continued growing: 400, 450, and finally 475°C! And again 475°C. The figure remained the same for a minute. The growth of temperature ceased, and at the same time the velocity of the vehicle, measured by the change in frequency of the on-board transmitter, became equal to zero. It could mean only that the lander was on the surface of Venus. The temperature was about 500°C and the pressure was nearly 100 atmospheres. Those conditions were sufficient to soften steels of ordinary quality. But the body of the vehicle made of refractory alloys withstood the hot embraces of Venus.

Up till then the path of all the Venera probes ended on the planet's dark side. A lander of the new Soviet inter-

planetary vehicle Venera 8 was destined to first soft-land on the sunlit side of Venus. However, the new lander's daylight "jump" proved to be much more complicated than the night landing of the preceding vehicles.

The reliability of radio communication between the Earth and a space vehicle is primarily conditioned by the distance between the two objects. Hence, the station was to reach Venus before the planet departed far from the Earth. Since the Venus' orbit is closer to the Sun than the Earth's, the planets reach the maximum proximity when they are both on the same side in respect to the Sun. As this takes place, the dark Venus' side facing the Earth becomes unseen to a terrestrial observer. When the planets, upon reaching the maximum proximity, begin to part, we can see a portion of Venus' disk as a bright crescent. It was onto this narrow crescent that the new Soviet lander had to touch down.

The difficulties of landing onto the sunlit side of Venus were not confined to what has been expounded above. The flight was to end in a steep descent through the atmosphere and the vehicle could have found the overloadings too great to withstand. If the descent had taken place along a very gradual trajectory, the vehicle could have missed the planet. Under the circumstances the vehicle had to approach the planet so that the atmospheric entry angle should have been neither greater nor smaller than the calculated one. That is why the landing area, suitable in all respects, was no more than a tiny spot on the sunlit crescent of waning Venus.

It is incredibly difficult to hit the target. And this is where the space "marksmen" – specialists in ballistics – are aided by what seems to be the main hindrance, namely tens of millions of kilometres separating the "marksmen" from the "target". The enormous distance enables them to make corrections in the direction of vehicle's motion on its way to the destination. Indeed, to cor-

rect the trajectory one must know exactly the position of the target, or the planet, at the moment of vehicle's approach. Astronomers had determined the position of Venus at a rendezvous with it. But an accurate landing required course corrections. Those corrections were obtained owing to regular radio location of Venus from the Earth throughout the flight.

Ballisticians coped with the difficult problem all right. The Venus 8 lander touched down exactly at the preselected place.

The automatic laboratory began operating as early as during its descent by a parachute. It was the first time that the atmospheric temperature and pressure were measured on the sunlit side of Venus. It turned out that there, too, the characteristics varied with altitude in nearly the same way as on the dark side of the planet.

The cloud cover, which forever obscured Venus, has from time immemorial made it one of the most mysterious planets of the solar system. But, the scientists attach no less importance to the study of the Venusian clouds themselves than to what they conceal underneath. There are some important reasons for this.

Venus, closer to the Sun than the Earth, is heated to such an extent that zinc or lead, if they were found there, could exist only in a melted state. At such temperatures and under such a great pressure life on the planet's surface is practically impossible. However, in the high-altitude clouds the conditions are quite different. Pressure, there, is not high and temperatures are moderate, approximately the same as we have on the Earth. Thus, could it not have been the clouds that were the cradle and the preserver of life?

The biologists answered the query by asking what the clouds consisted of. This was a question to which no answer could be furnished. There were various assumptions. Most odd compounds vied for the priority to be

among substances entering into the composition of the Venusian clouds. The American astronomer S. Rasool, for example, thought that the most suitable material for them would be toxic compounds of mercury. There was agitation among astronomers also when the Soviet physicists discovered the so-called anomalous water, denser than ordinary water. According to some planetologists, it was the anomalous water that constituted the Venusian clouds. Later, some researchers asserted that the clouds contained ammonia.

By that time the problem of the cloud composition became so topical that it was decided to tackle it without delay. The Venus 8 probe was equipped with a device to search for ammonia. When the probe lander was descending by a parachute, the device showed the presence of ammonia in the clouds. But even this finding did not put an end to the controversy.

To unveil the cryptic planet it was necessary to slightly open the cloud cover of Venus and to see what it was like at the surface. But it is only in open daylight that something can be seen clearly. Couldn't be the planet a captive of the eternal darkness? During the descent of Venus 8, a photometer was measuring the illumination intensity. The lower the vehicle descended, the darker the surroundings became, though a sufficient amount of light still remained. And now we know that there is as much light on Venus at noon as there is on the Earth by a cloudy day.

The probe had been operating at the surface of Venus for about an hour. The probe designers had employed new means of heat protection – materials of a very high heat capacity. When the fiery gases enwrapped the vehicle, it was those materials that absorbed a considerable part of heat and guarded operating instruments against immediate heat exposure. One of the instruments, a gamma spectrometer, was the first to examine the chemi-

cal composition of the Venusian soil. The instrument "scrutinized" the soil while being inside the sealed compartment.

Rocks can be distinguished by the quantity of radioactive elements contained in them. The gamma radiation resulting from their radioactive decay testifies to their content. The gamma spectrometer measured the intensity and energy of gamma radiation of the surface at the place of landing. According to this technique, the Venusian rocks were found to be similar to the terrestrial granites.

The summer of 1975 witnessed two Venera spacecraft of a new type launched from the Soviet cosmodrome in the direction of Venus. They were destined to become the *first artificial satellites of the planet*. The previous vehicles were of no avail for the purpose. That was the reason why the designers thought of the Mars spacecraft. Didn't those vehicles coped with a similar problem as far back as in 1971 and 1973? Well, certain changes had to be introduced into the Mars orbiters. For instance, the solar-cell panels could be reduced. Venus is closer to the Sun than Mars, and that is why the thermoregulating system had also to be changed. The big "Martian" antenna also became redundant, since the distance between the Earth and Venus is not so great.

The interplanetary flight lasted more than four months. Two days before the arrival to Venus, landers separated from the carrier vehicles. The landers were bound for Venus, as before, while the vehicles took up new trajectories about 1,500 kilometres above the planet's surface. Exactly at the appointed time braking engines of the Venera vehicles slowed down their movement, and they became orbiters, Venus' satellites.

The vehicle-borne scientific instruments examined the planet for several months. They measured the composition and physical characteristics of the upper atmosphere layers, temperature of the upper boundary of cloud

cover, interplanetary magnetic fields in the neighbourhood of the planet.

Now, let us go back to the landers. They had to be constructed anew. The wide "skirt" round the instrument container is a kind of metal parachute. This aerodynamic braking device, as it is called, retarded the lander's movement in the thick atmospheric layers of Venus after the genuine parachutes had been jettisoned. You do not see any big antenna on the lander. It was dispensed with since the lander transmitted the information not straight to the Earth, as before, but to the orbiter that was circling the planet not far off; and it was only from there that the signals were sent to the distant-space communication centre. On the lander's sides you can see its "eyes", telephotometres. It is thanks to them that we were able to see the surface of Venus for the first time. And here is the story.

"The ground-based telemetry station began reception of the image of Venus' surface. The quality of the image is good". The announcer's words compelled the attention of all present in the control room. No one knew what picture the electron beam was about to draw on the TV screen.

Then came the answer. Academician M. V. Keldysh, on scrutinizing details of the picture, said, "As far as its definition is concerned, what we see here is by no means inferior to the first lunar panorama". This opinion was shared the next day by one of the directors of the National Aeronautics and Space Administration of the USA, "The pictures received show that carbon dioxide at the surface is beyond any doubt transparent and that the light reaches the surface through a thick layer of clouds."

Stones. They are perfectly distinguishable, well-lit, clearly outlined, with shadows that are dense but not sharp. Big boulders and small fragments. Newly-formed

stones with uneven and sharp edges. Old ones of a rounded shape with smooth sides. What factors could account for smoothing out sharp edges of the Venusian rock? On the Earth it is wind, water, temperature variations. And on Venus?

Three days later Venus 10 revealed us quite a different picture. The probe stood on a bright and smooth slab with serrated edges and deep fissures. Similar bright islets, evidently outcrops of the rock, are scattered around as far as the "eye" could reach. They are interspersed with dark, almost black soil. Everything is smooth, with no stones in sight.

The pictures of Venus aroused our interest in the Earth's space neighbour, but it was only three years later that our thirst for new knowledge could be quenched. Ballistic "gaps", or favourable periods of launchings to Venus, are not frequent. That was why both leading space powers, the USSR and the USA, availed themselves of the opportunity next in turn. Venera 11 and Venera 12 were launched from the Soviet cosmodrome, while Pioneer-Venus 1 and 2 were set off from Cape Canaveral.

The new Soviet probes were of the same design as their two predecessors. Each of them carried a lander and served as a flying repeater like previous vehicles, with the difference that earlier the vehicles became Venus' artificial satellites, while now they, in transit, had to send back to the Earth the information from the landers, and then continue their flight round the Sun.

Different assignments were in store for the two Pioneer spacecraft. The first vehicle was designed as the planet's satellite, the main aim of the other was to deliver four probes into the Venusian atmosphere.

The Venera landers parted from their carriers not long before the end of the flight. The landers continued their flight to the planet, while the carrier vehicles changed

over to trajectories at an altitude of over thirty thousand kilometres above the planet. Their function was to receive information from the automatic "scouts" and pass it on to the Earth.

When the two landers were entering the atmosphere of Venus, the Mission Control Centre was still at dark. And where the Earth's envoys were swinging on multicolour parachutes, the Sun shone brightly. This was also confirmed by instruments measuring the brightness of the sky above them. The landers were diving into the atmosphere deeper and deeper. The temperature and pressure continued to grow.

They entered the clouds without incident. What seemed from afar to be a thick and dense cover was actually only a thin haze. As was established, the deceptive appearance could be accounted for the many-kilometre thickness of the cloud cover. The composition of the Venusian clouds had not been known. There were quite a few assumptions on this account. The terrestrial observations prompted that the nebulous shroud, concealing the planet, had to consist of drops of some sort of liquid that did not freeze even at hard frosts that reign in the upper cloud region. The American scientists Sill and Young have discovered that these and other properties appropriate to the given case were displayed by concentrated sulphuric acid.

Every 10 seconds spectrometers were switched on within and under the clouds. And each time the surrounding gases left their marks on the spectra. The probes examined the clouds "by touch", so to speak. Samples were taken from the clouds, filtered, and then arrested cloud drops were exposed to radiation by radioisotope sources. This resulted in excitation of X-ray radiation in the substance of the drops, thus identifying the emitting atoms and molecules. Quite unexpectedly, chlorine was found in the clouds in association with sulphur.

Two weeks earlier Venus had been reached by four probes from the American spacecraft Pioneer-Venus 2. Before separating three smaller probes, the vehicle was spun and the centrifugal force set them apart. All this proved the conformity of the appellations with which the probes were provided, viz. "North", "Day", and "Night". The first came into the atmosphere in the dark part of the northern hemisphere. The other two appeared in the day and night sides of the southern hemisphere. The fourth, bigger probe, as distinct from its associates, descended by a parachute and investigated the equatorial zone. Pioneer-Venus 2 itself, as had been envisaged by the programme, burnt up in the atmosphere.

The similarity of scientific problems rendered a rare opportunity to compare the results of the Soviet and the American measurements. In all the six regions of Venus (our second lander touched down at the distance of 800 kilometres from the first), the cloud cover was situated at approximately the same height and had practically the same thickness. The unexpected confirmation of the sulphuric acid hypothesis was furnished by ... temperature sensors. On all the four American probes they failed at the altitude of about 12 kilometres. According to one of the scientists, by that time the acid had corroded the exposed parts of the probe. However, it should be borne in mind that hydrochloric acid (comprising chlorine found in the clouds) has a no less ruinous effect on metals than sulphuric acid.

The Soviet landers were the first to be provided with *lightning recorders*. With their help the scientists made an attempt to find out what processes influence the composition of the Venusian atmosphere. It is a well established fact that on the Earth thunders are responsible for the formation of ozone and nitrogen oxides in the air. There is every reason to believe that frequently occurring strong thunders could well have accounted for the luminescence

of the night sky on Venus. The lightning recorders managed to detect strong and prolonged electric discharges. Were they really caused by lightnings? This is something that called for further study.

Having measured the temperature at the surface, the new Venera probes showed the very same 470°C. This made the scientists think of the causes of the planet's heat-up. The "greenhouse effect" has been considered responsible for it. The sum and substance of it consists in that carbon dioxide, which accounts for 95% of the planet's atmosphere, lets incoming solar radiation to the surface but withholds reflected thermal radiation. Quite recently a rival hypothesis has been proposed.

In an attempt to explain the slow rotation of Venus (the solar day there, as has already been mentioned, lasts for 118 Earth days) by the influence of a massive natural satellite that had left the planet forever some time in the past, the astronomers, to their surprise, have recognized it in Mercury. Computer calculations of changes in the movement of Mercury placed in a Venus' satellite orbit have produced ample proof that the flight of Mercury from its "hostess" was inevitable indeed.

But if both celestial bodies, at some distant time in the past, were so closely bound, their interaction must have been accompanied by release of a vast amount of energy. A considerable part of the energy must have been spent on heating up the depths of both planets and an intensive liberation of gases from the original planetary matter. However, only experiments could either sustain or reject the assumptions concerning the kinship of the two planets.

What was required, first and foremost, was to determine the content of inert gases in the Venusian atmosphere. The fact is that having entered the atmosphere as far back as when the planets originated, they could no longer be chemically bound to any other element, and

thus remain practically invariable witnesses of the earliest stages of their evolution.

It was particularly important to know the relationship of various isotopes of argon. On the Earth argon is represented mainly by a heavy isotope with atomic mass equal to 40. It is formed as a result of radioactive decay of potassium with the same mass, and its quantity in the atmosphere builds up gradually. On the contrary, the quantity of light isotopes in the air is smaller and does not practically change with time.

Since the age, mass, and dimensions of Earth and Venus are nearly the same, there would be every reason to assume that the two planets did not differ from each other as far as the content of argon in the atmosphere is concerned. If, on the other hand, Venus had really passed through a period of wanton development, connected with the satellite and accompanied by an intensive liberation of volatile substances from its depths, then the relationship between light and heavy isotopes of argon on it must be higher than that on the Earth. So what do we find?

It has been established that the quantity of light isotopes of argon on Venus is almost the same as the amount of its heavy counterpart, while the total quantity of argon in the Venusian atmosphere is approximately one hundred times less than its content in the Earth's air. A new puzzle has presented itself. Doesn't this result mean that processes of the Earth and Venus formation from a protoplanetary nebula had been developing along different lines from the very start?

One of the most conspicuous peculiarities about Venus is associated with water. All the water on Venus is dissolved in the atmosphere. At the high-temperature surface even when under pressure of 100 atmospheres, liquid water cannot possibly be found. As compared with the Earth, the quantity of water vapour in the Venusian atmosphere is extremely low. It is highly significant to

explain this phenomenon. If there had been more water on Venus, there would not have been such an abundance of carbon dioxide. In exactly the same way as on the Earth, the latter would have interacted with water, forming solid carbonate rocks. But the less carbon dioxide, the weaker the "greenhouse effect" and, consequently, the lower the surface temperature, and so forth.

It is of no minor interest that the atmospheric dryness can partly be explained by the presence of sulphuric acid in the clouds. Its concentrated solution is remarkable for absorbing water. But, perhaps, there has never been much water on Venus? As is so often the case with science, answers to one question give rise to a great deal of new questions instead. They could be solved only if a new research were undertaken. This is why in autumn 1982 a pair of new Soviet interplanetary spacecraft started out on their flight to Venus. Venera 13 and Venera 14 were intended to throw some light on the problems that cropped up during the preceding flights, and carry out quite new experiments.

In the panoramas sent back from Venus, a number of which were photographed successively through red, blue and green light filters, we saw the landscapes of Venus that were quite new to us. The photos helped us to imagine what human beings would see if they found themselves at the surface of Venus. This is how one of the participants of the space experiment put it, "What we don't see here is a usual blue of the sky we have on the Earth. High above the surface there is a huge dome of orange clouds. The lowest of cloud layers are at the height of 48-49 kilometres. They are so high that it is hardly possible to discern any features of their structure from the surface, with the exception, perhaps, of narrow bands (something like terrestrial cirri), situated a little below 48 kilometres.

"When the local time approaches 6 o'clock, auroral

rays of the Sun illumine half of the cloud dome and cast a faint light on the other half. It must be really beautiful to watch it all from the surface of the planet. The clouds gain more and more light, and the firmament is gradually becoming bright in all its parts.

"... The sky over the horizon has a bright yellow-green tinge. ... It is exactly the yellow-green sky that can be seen in the colour panorama around the landers of Venera 14 and, particularly, Venera 13, where, due to the uneven terrain, one can see a slope of the next valley through a yellow-green haze".

The value of the colour pictures sent back by Venera 13 and Venera 14 can hardly be overestimated. And this is not simply because it is always interesting to see something that no one has ever seen before. The pictures have brought information of enormous significance. They have produced dozens of interesting leads concerning the geological history of the planet as well as giving an idea of the conditions currently reigning on this unknown world. The images of Venusian ground, which have covered tens of millions of kilometres to reach us, levelled to the ground, figuratively speaking, a large number of hypotheses, at the same time confirming some other assumptions.

In the panoramas the scientists saw a new proof of the volcanic activity on one more planet of the solar system. Data obtained by means of other instruments testified to the same, e. g. readings of atmospheric electric activity meters. The comparative study of information received from the "Groza" lightning recorders installed on the preceding and subsequent stations, brought the researchers to the conclusion that lightnings on Venus do not originate in the clouds, but above the continually and powerfully erupting volcanoes.

Presumably, the failures of temperature sensors in the American spacecraft, of which mention was made above,

were caused not by the chemical activity of acids suspended in the atmosphere, but by the electrical activity of the volcanoes.

The landers of both Venera 13 and Venera 14 were the first probes to be equipped with special devices for taking soil samples from a certain depth and carrying them into the probe for analysis. The soil-scooping tools were working as if in a fiery furnace. Not every metal remains solid under similar conditions. But the tool had not only to retain its properties, but also to perform complex manipulations, rotation, and change modes of operation. The automatic samplers coped with all that successfully. Soil samples were transported into the probes and subjected there to an elaborate analysis.

Being in possession of the TV images of smaller areas and the global map of the planet's surface that had been made up with the help of terrestrial radiolocation, the scientists were deprived of the opportunity to see structural details of any large areas of Venus. The next interplanetary probes were commissioned to fill up the gap. Venera 15 and Venera 16 did not carry any landers; however, they were equipped with powerful radars. From Venus' satellite's orbits, the probes were conducting a detailed mapping survey of the planet's surface. All seeing radio waves penetrated the clouds and, reflected from the surface, carried to the probes information on its structure.

The explorations of Venus exemplify the characteristic features of the Soviet space science. It has set itself more and more complex tasks, and created ever more sophisticated technology to accomplish them; this is its path to success.

On a Visit to a Comet

The comet returns. There are not many who can proudly say that they have seen Halley's comet. It adorned

the sky for the last time some seventy five years ago. Its appearance was foretold and expected. As is usual in such cases, the layman got a scare, while the newspaper headlines were enhancing pessimistic forebodings by raising such questions as, "Will the Earth perish in the current year of 1910?" The beginning of the twentieth century was really disquieting.

But, fortunately, on that occasion the comet passed the Earth harmlessly. After that the world became absorbed in events that were much more significant. 1917, the year of the Great October Socialist Revolution, saw the comet in the neighbourhood of Uranus' orbit, and by the end of the Second World War it had reached its maximum recession from the Sun and turned back. Now the celestial wanderer is again approaching us. In winter 1986 it will pass the perihelion, or the point in its path that is nearest to the Sun. At this time the astronomers of the northern hemisphere can encounter the comet in the evening, while their colleagues living to the south of the equator will have to get up very early in the morning to do this. The cosmic guest will appear before the scientists as a hardly perceivable shy nebulous spot among the stars and will seem much weaker than the brightest of them.

The date of Halley's comet discovery is entered in hand-books with the minus sign, which means that people had seen it as far back as before Christ. But the comet is particularly valuable to the astronomers not only as an old acquaintance. Though an undistinguished member of the family of minor celestial bodies, it was the first to give detailed account of its relatives. Calculations pertaining to its movement have most convincingly proved the tenability of Newtonian mechanics and showed that the comets actually revolve round the Sun, while the observations of 1910 provided the first evidence of their physical nature.

Today, the researchers of comets cannot remain indif-

ferent to the success attained by their colleagues, the planetologists, who have already "visited" Mars and Venus, and sent the probes to Jupiter and Saturn. "It is only the flights to comets that can give us a 'quantum jump' in knowledge, which is so essential for the solution of the fundamental problems of comets", wrote the American scientist F. Whipple as early as the seventies. It was the time when one of the authors of the present book met the famous Soviet cometologist Academician O. Dobrovolsky and made the following note of what the scientist said, "The launching of the rocket probe to Halley's comet. In 1986 it will pass the perihelion. It will be one of the most appropriate cases in the second half of the twentieth century for such a mission".

The childhood of the solar system and its witnesses. Let us bring back to our memory the first interplanetary flights. It is hardly feasible that the question "what for?" could have arisen then. At long last it was possible to do what Konstantin Tsiolkovsky described, i.e. "to lift the stone from the Moon, watch Mars at a distance of several miles, and descend even to its very surface". The scientist's dreams were implemented into reality. It was the first time that the possibility to get in touch with the remote and alien worlds had come into effect. No, the question "what for?" could have hardly arisen then. The question "when, then?" had superseded all others.

Now, what about the comets? Will the aim justify the means that will have to be spent on the missions to them? The times when the appearance of tailed celestial bodies signified the inevitability of the forthcoming disasters have long gone into oblivion. Today even schoolchildren know that comets are nothing but lumps of dirty ice emitting "smoke". Nothing else? Why is it then that one of the most interesting projects of the children's competition, held several years ago and connected with the best

space experiments, was devoted to the docking with a comet? This means that the idea has really ripened, if it has occupied the minds of the future scientists.

Comets are the least investigated objects in the solar system. As distinct from the planets that are practically always observable, bright comets appear in the sky only twice or three times within a century and display themselves only for so little a time as weeks or months. Smaller comets, due to their small size and atmospheric disturbances, are even more difficult to observe.

In spite of highly convincing indirect evidence, the "ice" hypothesis continues to remain only a tentative assumption. So far, it is unknown what constitutes cometary nuclei. Meanwhile, their composition and properties might conceal the mysteries the discovery of which could throw light on a host of problems pertaining to the origin and evolution of the solar system.

The fact is that comets are by no means ordinary ice. Their nuclei have forever borne the impression of those distant times when on the cold outskirts of the original gas-and-dust cloud giant planets were being originated. By their attraction they assimilated a part of comet bodies, while the other part was cast away to the periphery, where it formed a huge aggregation of ice lumps. It has been supplying the neighbourhood of the Sun and the Earth with comets up till now.

As distinct from many planets, minor celestial bodies of the solar system have not passed through the stage of heating-up in their development since their mass is too inconsiderable. But are we justified in speaking of any evolution, if in the comets, as in a refrigerator, the original substance has remained intact for thousands of millions of years? There are different opinions as well. The Dutch astronomer J. Oort, for instance, says that comets are a thousand times younger than they are taken to be. He suggests that comets are ice fragments of the planet

Phaethon that had revolved round the Sun between the orbits of Mars and Jupiter and exploded about five million years ago. Such was the unfortunate outcome of what had been the planet's accidental proximation with Jupiter, the tide-raising forces of which caused the overheating of the planet's depths.

The Kiev astronomer S. Vsekhsvyatsky is adamant in his opinion that many comets can be rightly considered to be our contemporaries. He has further elaborated the hypothesis advanced by the French scientist Joseph L. Lagrange as far back as in 1812 and thinks that the nuclei of comets are fragments of satellites of the giant planets, that were erupted into interplanetary trajectories by the active volcanoes.

Photographs showing powerful eruptions on the Jupiter's satellite Io have recently been received from space vehicles thus encouraging the proponents of this theory. However, the discrepancy in the opinions can be resolved only by a more proximate acquaintance with the celestial wanderers. In any case, irrespective of who will turn out to be right, the flight to a comet will be a marked event in the development of the scientific study of the Universe.

Comets and life. The space icebergs draw the attention of not only the astronomers. According to the English astrophysicist F. Hoyle, meteor showers of cometary origin are sowing the planets, including our Earth, with microorganisms. It is in them that the researchers see the cause of coincidences of some outbreaks of global epidemics with the Earth's passage through meteor streams.

The possibility of associating the origin of life on Earth with comets has been seriously discussed in scientific circles. Thus, the forthcoming return of Halley's comet made it quite opportune for the distinguished American

biologist and chemist C. Ponnamperuma to convene a conference devoted to this problem at the University of Maryland.

It is yet unknown whether comets were really the cradle for viruses and bacteria. The supposition that organic substances could be found in their nuclei is by no means of recent origin. In fact, why should there be any doubts about it? The elements of which they are formed are most definitely contained in the comets. The fact that outer space is a quite appropriate environment for the synthesis of organic molecules is substantiated by their presence in meteorites and even in interstellar gas.

And not only that. An American scientist, having irradiated the frozen mixture of water, methane and hydrogen, discovered traces of carbamide and acetic acid in it. Soviet scientists, in their turn, have discovered chemical reactions at extra low temperatures. One of the authors of this discovery Academician V. Goldansky made the following straightforward statement, "There is every reason to assume that in the cold of outer space and under the action of cosmic radiation, slow but steady processes involving the formation of most complex molecules, even proteins, can take place. The possibility arises of what I would call the 'cold pre-history of life'."

In laboratories of the Leningrad Physical-Engineering Institute of the USSR Academy of Sciences and the Institute of Astrophysics of the Tajik SSR Academy of Sciences experiments with models of comets are being carried out. A vacuum chamber and a refrigerator of the experimental set-up simulate the space environment, while various light sources are used in place of the Sun. Illuminating a piece of ice with light of various intensity can serve a good example to illustrate the "flight" of an artificial comet round the "Sun".

Quite by chance the validity of the method employed was proved by space vehicles, artificial satellites of Mars.

In Tajikistan, as elsewhere, their flight arose everybody's keen interest, which was not purely professional, for the Institute is not directly concerned with planetary studies. But there was a piece of news from Mars that was particularly welcome there. The temperature of the north polar ice cap on Mars was equal to that of the artificial comet to an accuracy of two-three degrees, both the "comet" and the Red Planet being "at the same distance from the Sun".

One of the first organic compounds which the scientists decided to include *a priori* into the composition of their models was methyl cyanide. The choice proved to be extremely successful. Only several months later, radio astronomers were able to detect in the spectrum of the then brightest Comet Kohoutek the radiation of molecules of this substance. An article, ready for publication, had to be urgently revised, since methyl cyanide was transferred from the category of those that might exist in comets into those that actually exist. Other organic compounds were also found in Comet Kohoutek.

In the course of experiments a rather interesting phenomenon presented itself. Upon sublimation of ice from the "cometary nucleus", into which organic substances had been introduced, a crust was formed on the solid residual in the vacuum chamber. The crust consisted of finest parallel filaments. Under the microscope, each hair of the "brush" turned out to be an icicle, hidden behind a densely wound spiral of interwoven molecules of biopolymers. The filaments received the name of biological sublimated construction, or biosublicons in short. The ice basis was good enough for holding the chain of molecules, and thus the construction could become fairly strong. If, however, the "comet" residual was heated, the ice core evaporated, and the vapour drew turns of the spiral apart and they became not only easily distinguishable, but movable as well. Hence, in the artifi-

cial comet organic molecules form chains connected by a chemical bond.

Thus long organic molecules are rolled into a spiral! One could not help thinking of a famous double spiral of DNA, the basis of heredity. That was why included into the composition of man-made comets were amino acids, of which proteins, essential to all living organisms, are constructed as well as nucleotides, structural units of nucleic acids. The result was fascinating. In forming biosublicons, both amino acids and nucleotides were helping one another – chains of amino acids served as matrices during the "assembling" of nucleotides and vice versa. All this unambiguously reminded of what happens in living cells.

But a model remains only as such. Have the scientists managed to take at least a cursory glance at something that undoubtedly take place in nature, or what we have is nothing but an interesting experiment? The confines of a laboratory experiment will always leave room for doubts. They can be resolved only by a direct contact with a comet, which would promise the said "jump" in our knowledge.

Fiction or reality? A bright spark has appeared in the field of the heading sensor; swinging to and fro it has moved to the centre and begun growing. It is just one more star similar to thousands of those that passed by before. Shortly the twinkling spot becomes surrounded by dimly shining dots, also gradually increasing in size. They are the cold satellites surrounding the star. Now the probe cannot turn aside because the programming device considers planetary systems a priority.

The tactics of circumnavigating this family of celestial bodies was also determined by the logic stored into the automatic device at the time of probe's launching hundreds of years ago. Following it, the probe has to fly by in the neighbourhood of solid-surface planets possess-

ing a well-developed atmosphere. Cold gaseous spheres on the periphery can be investigated from afar, the route always being far away from a fiery celestial body in the centre.

The probe's research complex had to do some particularly hard work in the neighbourhood of three small planets. In spite of the proximity and almost equal dimensions, these star satellites were not twins. One of them was cooled off and almost deprived of its gaseous envelope, while the other, on the contrary, was hot and covered with a dense opaque atmosphere. The third was neither hot nor cold, wrapped up in water vapours, white shot with bluish.

It was this white-bluish globe that made the probe put in so much work – the planet was generating regular electromagnetic radiation without ceasing. After rummaging in its memory, the robot discovered something similar that had occurred before. It was at the outset of the flight when it was made to assess its own world that had set it off. It was precisely the same case now, and the robot impartially gave its verdict... the planet under investigation is inhabited!

And now let us compare the above fictitious events with a factual account. "In 1881 the Bristol astronomer Denning discovered an interesting comet. It was unusual in many respects. It did not approach the Sun too close and had practically no tail – the main attribute adorning almost all comets. It came very near to the Earth – at the minimum distance of 6 million kilometres. Moreover, it flew by only 9 million kilometres away from Mars. The comet was observed as an inconspicuous and nebulous disk-like spot with shining dots in its centre. It should be added that the comet passed Venus' orbit as close as 3 million kilometres away and at a distance of 24 million kilometres from Jupiter's orbit.

Isn't it all very interesting? The Soviet scientists

V. Burdakov and Yu. Danilov did not leave such an unusual behaviour of Comet Denning unheeded, though they, certainly, did not assert that at the end of the last century the solar system was visited by an ambassador of some unknown civilization. There was no enough ground for any assumption of this kind, though it has not only been this comet that gave rise to the question whether it was possible for intelligent life to migrate throughout boundless cosmos on islets which we, the terrestrial observers, erroneously take for comets.

Even by making use of all the known data, the shape of Comet Arend-Roland, especially its "nose cone", does not lend itself to be explained by natural causes. The same can be said of the comets' radio emission. Most probably the explanation lies in the fact that we are still ignorant of many laws governing the manifestations of tailed celestial bodies. But isn't it surprising that the strange comet had such a marked resemblance to an interstellar vehicle provided with a direct-flow space engine, over which designers of various countries have been racking their wits for a long time? And if scientists firmly believe that only in 150 or 200 years' time they will be able to send hundreds of people on a space journey unlimited in time, why should we then deprive our "brethren in intellect" of the like possibility?

At the space crossroads. The minimum information we should possess in order that we could meet someone, consists in knowing when and where our paths can cross. The flight direction of a space vehicle can be both given and maintained. But it is impossible, as a rule, to know the exact cometary orbits. The reason lies in instability of movement of these small celestial bodies. They are too easy to be led astray from the "path of the righteousness". Suffice it for a comet to pass in the vicinity of a giant planet, then comet's trajectory shifts. And not only

that. Its own "rocket engines"– unpredictable streams of gas and vapour sprayed by the nucleus – also set the rockets off their "preselected" route.

One of the possible means of guiding a space vehicle on its target comet is to photograph the comet regularly as the vehicle approach it and then to compare the pictures taken with the data of star catalogues and astronomical observations. In so doing, the nearer to the nucleus, the more frequent are the pictures sent back from space.

Comets are too small to be noticed from afar, and when they are at considerable distances, they do not *yet* become visible. When, however, they come closer to the Sun and the observer, they become discernible, but their nuclei are *already* found to be invisible since they get surrounded by their own vapours. Hence, only a nebulous envelope concealing the nucleus makes it possible to speak of its composition. At first glance, nothing seems to be simpler. A substance from one state transforms into another, as is, for instance, the case with water and vapour. But in actuality things are not always so simple and turn out to be extremely complicated.

The fact is that solar radiation and cosmic rays destroy molecules that are leaving the nucleus. Besides, the very same "fragments" can originate from totally different substances. But, that is not all. Parts into which molecules of these substances (they are accordingly called parent) decompose are very active and "willingly", though often in quite different ways, combine with one another, thus forming new chemical compounds. Hence, intact molecules to be found in the comet heads do not clear up whether they are products of vaporization or of secondary synthesis.

The cometary nucleus lends itself to observation and analysis only when it is approached at a close range. But an envelope of gas and dust surrounding it reaches sometimes a million kilometres in diameter, and, conse-

quently, the space vehicle will find itself obscured by a nebula shining in the Sun long before it can reach its destination. That is why the probe, with its electronic eyes and brain, would have to commit itself to final highly important corrections of the trajectory.

One would welcome the opportunity to be in the neighbourhood of the nucleus for a greater time. But Halley's comet, for instance, revolves round the Sun in the direction opposite to the movement of the Earth, so the nucleus, travelling at an enormous speed, may appear just for a moment in the probe's field of vision. Will deceleration help? This would require a considerable amount of fuel which would substantially increase the launch weight of the probe. Besides, the Halley's comet orbit, as well as the orbits of many other comets, has a marked inclination in respect to the Earth's orbital plane, and the vehicle cannot change over from one plane into another without spending much energy. Certainly, we could fix the rendezvous for the moment of comet's crossing the Earth's orbital plane and thus do without additional ignitions of the rocket engine, though in this case the rendezvous is unlikely to be long.

What has been said above is meant to give the reader an idea of what our probe's first meeting with Halley's comet will be like. Having been launched from an Earth satellite's orbit and left behind the planet, the vehicle, on the head-on course, will fly by near the comet, which, by that time, will have passed the perihelion, though still remaining bright and active. The attitude control system will manage to extend the time of investigations acting as a photographer on a moving train. It will be smoothly turning the lenses of scientific instruments and television cameras to follow up the nucleus reluctant to have its picture taken.

Saturn's captives. Strange as it may seem, but comets have been drawing the interest of space vehicles for some

time already. As far back as in 1970 the artificial Earth satellite discovered a comet's hydrogen atmosphere, with its dimensions exceeding the diameter of the Sun. Ten years later no less significant discovery was made by an interplanetary probe. The instruments of the Venera spacecraft next in turn, directed at the newly discovered Comet Breadfield, registered in its composition elements that had not been found before. An exceptionally rare phenomenon, the collision of a comet with the Sun, was reported from outer space. Such events often remain unnoticed due to difficulties of observation in the bright sunlight. This accounts for the appreciation of the photographs sent back from orbit. In them we can follow a comet, with a tail 5 million kilometres long, speedily approaching the fire-spitting Sun, fragments of its nucleus dispersing in various directions.

There might be some evidence that a cometary nucleus was photographed "close-up" from outer space. In autumn 1981 the American spacecraft Voyager II sent back to the Earth a picture of Phoebe, the remotest satellite of Saturn. Moving, for some inexplicable reason, towards all the other satellites of the giant planet, it has been drawing particular attention for a long time. What makes the scientists consider Phoebe a comet captivated by Saturn's attraction is its colour. The mineral dust, the particles of which could have not resisted the gravitation of a large body, must necessarily cover its surface with a dark crust of the type that is seen in the photographs taken by Voyager.

It may well be assumed that Saturn has ice captives of smaller dimension, the mass of which is insufficient for the complete obstruction of their activity. The Soviet researcher V. Davydov considers that these ice lumps with "smoke-emitting" tails, wound on orbits round Saturn, can be directly responsible for the formation of the well-known rings. Thus, what we have instead of a

uniform distribution of mass throughout the ring is one active comet-like nucleus in each ring. The rings themselves are paths closed round the planet and filled with "smoke" emitted from the nuclei. Davydov's hypothesis is gaining more ground particularly because it helps to explain the mysterious character of the Saturn's outermost ring, which consists of several light-colour threads braided into a "plait".

A rendezvous with the comet. The medieval Italy also saw Halley's comet. It was then that the great Giotto di Bondone perpetuated it in one of his frescoes in the Arena Chapel of Padua. But instead of the conventional angels, the blue of the sky above the kneeling magi is cut across by a tailed fiery ball. And now, seven centuries since his death, the great painter is going to meet his model again. The vehicle to be sent off towards Halley's comet bears the name of Giotto.

The decision to arrange the space rendezvous was taken by the European Space Research Organization (ESRO) in 1980. Main tasks of the flight have been mapped out. In July 1985 the French rocket Ariane 2 is injecting Giotto into an interim Earth satellite's orbit. Then, by igniting the engine at the apogee, the space vehicle will change over to a trajectory leading to Halley's comet, and in 8 months' time it will pass through its tail at a distance of the order of several thousand kilometres from the nucleus.

Flying by, Giotto will be examining the comet for about four hours. During this time it will photograph the nucleus (the scientists expect to distinguish comparatively small details in the photos), while scientific instruments will make a study of particles of dust, charged particles, atoms and molecules of emitted gases, all constituents of the tail.

The US National Aeronautics and Space Administra-

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tion (NASA) is planning to conduct observations of the comet with the help of an ultraviolet telescope, installed on a manned spacecraft of the Space Shuttle type. The telescope is to be put in near-earth orbits three times (each time for a week). The first run falls on autumn 1985, when Halley's comet will be at a distance of 80 million kilometres from the Earth. The second run is planned for March 1986 during the fly-by of several probes in the comet's vicinity, and the last run is scheduled for summer 1986, when the tailed guest will be moving past our planet at a minimum distance.

Well, what about the Soviet Union? It goes without saying that the great power that was the first to pave the way to outer space cannot stay away from the events described here. Together with a number of the socialist countries, the participants of the Intercosmos programme, and the research organizations of France, Austria, and the Federal Republic of Germany, the Soviet Union is equipping a representative scientific space mission. Two automatic probes will be launched from the Soviet cosmodrome Baikonur. They will be modifications of the well-known Venera spacecraft. Their journey to Venus will last about six months. On sending landers to the surface of the cloud-covered planet, the probes will perform necessary manoeuvres to head for Halley's comet which by that time will have approached Jupiter's orbit. Nine more months will take them to reach the region at a distance of about a thousand kilometres from the nucleus in March 1986. A closer fly-by would be tempting though hardly feasible. The relative velocity of the two celestial bodies, man-made and natural, will come to approximately 70 kilometres a second. At such a high speed and at an enormous distance from the Mission Control Centre, when it takes a command several minutes to reach the vehicle, the danger of colliding with the hard nucleus becomes imminent.

The Soviet probes capable of being orientated about all three axes in space, as distinct from the spin-stabilized Giotto spacecraft, will be able to follow up the nucleus for a longer time. They are likely not only to send back images of the nucleus but conduct a whole complex of measurements within a wide wavelength range – from infrared to ultraviolet.

Rare astronomical phenomena usually stir up a global interest. Suffice it to recall the latest total solar eclipse when a large number of expeditions from all over the world gathered in the USSR to observe it. The investigations of Halley's comet will also acquire a world-wide character. Japanese scientists are going to take part in them too. Two Japanese space vehicles that are getting ready to the flight, sponsored by the Institute of Space Research and Aeronautics of Tokyo University, can contribute additional material to the data to be obtained by Giotto and the Soviet probes.

Thus, in spring 1986 deep space is expected to witness a large rally. Will Halley's comet withstand such a mass attack of space science?

Peeping into the future. But before we do that let us go back to the times ere long and bring back to our memory one of Voltaire's perspicacious fancies. In his story *Micromegas* he wrote, "... The comet passed very close to the last of the moons. They jumped onto it with their servants and scientific equipment". In those days the idea expounded by the French philosopher seemed to be no more than sheer imagination. Nowadays, however, its implementation is being discussed quite seriously.

Revolving round the Sun along elongated ellipses, comets now approach it, now depart from it at a distance of thousands of millions of kilometres. Besides, orbits of most of them are markedly inclined to the plane, in which all the planets move and man-made spacecraft fly. That is

why seems so attractive the idea of using comets for probing the Universe. They will be able to deliver scientific instruments to places that will remain inaccessible to Terrans till some time in the distant future. In order that this kind of goal could be attained, we should, first and foremost, cope with the problem of landing on comets. Let us embark upon the wings of our imagination and see how all this can come true.

... The screens have been lacking televiewers for many months already – the destination was still far away and no one was eager to merely gaze at the stars. The situation has not improved even when the space vehicle was already travelling within the comet's head. Though it did look like a shining nebula from afar, it turned out to be invisible from within, as is typical of a genuine galaxy. But, at long last, the nucleus came to sight. The bright spot was gradually getting bigger till it became an immense grey lump. It was strange to see it slowly roll in void, spitting steamy jets and spraying icy splashes now and again.

For several weeks the television cameras have been scrutinizing the comet. All that time the vehicle was circling, at times departing from the nucleus at a distance of tens of kilometres, at others approaching it rather close.

The decisive day of landing on the nucleus has come. It takes the radio command several long minutes to reach from the Earth. And now the space vehicle begins closing in. The nucleus image grows consistently, and shortly the whole screen gets occupied with a shimmering ice wall. At some particular moment the image gives a jerk, and enters into the picture a small rocket pulling behind itself a thin elastic rope. The rocket harpoon hits the ice, then penetrates it deeper and deeper; the rope gets tightened, and shortly the hollowed, cracked, dirty surface starts coming up to the televiewer.

It is hardly possible to say, that we shall meet a comet

in exactly or approximately the same way as it has been depicted above. Nor can we say with any degree of certainty when such a meeting will take place. To conclude this part of the book it would by no means be out of place to mention that quite recently Moonstone had been nothing but a venturous and unattainable dream.

What Is a Dream Today Will Become a Reality Tomorrow

"... To step on the ground of asteroids, lift a stone from the Moon, construct travelling stations in ether, form inhabited rings round the Earth, the Moon, and the Sun, watch Mars at a distance of several miles, land on its satellites or even onto its very surface... what can be more whimsical than all this?" These are the words of Konstantin Tsiolkovsky who said them only 60 years ago. The rapid development of space science has done much to implement Tsiolkovsky's ideas into practice. But there still remains something that is only a dream today and will become a reality tomorrow. What is it? It is difficult to foresee the future that lies centuries and millennia ahead of us; but we can make an effort to visualize the nearest perspective attainable within several decades to come.

The future of space efforts mainly depends on the economical means of power generation for launching manned and unmanned spacecraft into far-away space missions. All this should find its realization in developing radically new propulsion systems.

For instance, the peaceful atomic energy, which has so far been impressing us by the fantastic power hidden in the incredibly small volume of the nuclear fuel, is getting ready for space uses.

In an atomic rocket engine, nuclear fission energy of uranium or plutonium will be transformed into thermal

energy and will thus heat up liquid or gas that is passed through the reactor. Heated up to a temperature of several thousand degrees and then ejected through the nozzle, the vapour or the gas will produce a powerful thrust. We have already discussed electric rocket engines too. The future undoubtedly belongs to them.

Today, when the Earth is just beginning to come to know its nearest neighbours, the scientists are already thinking of flights to the stars. People will presumably take the risk of going on an interstellar journey only in a rocket the velocity of which will approximate that of light, or else the journey may take more time than the life-span. Prototype engines are being elaborated that are estimated to be capable of developing such velocities. The example that can be furnished is a direct-flow engine where instead of air such a "phantasmal" substance as interplanetary gas is supposed to be used.

Orbital stations of the future will have only a remote resemblance to the firstlings of space "house-building". In commodious premises there will be all the conditions for prolonged stay and normal work of large teams of spacemen. The artificial gravity will help to forget the inconveniences of weightlessness, and spacious greenhouses will, in many respects, solve the problems of food and air supply.

We think that we shall all be witnessing first habitations set up on the Moon, new space missions to the planets of the solar system, and then one of us will possibly take up a place at the controls of a first interplanetary liner...

It, certainly, belongs to the distant future. However, there are proximate aims that are also very attractive, for instance, the idea of using libration points. Let us furnish an example to illustrate the phenomenon under consideration.

In celestial mechanics there is a classic problem con-

cerned with the movement of three reciprocally attracting bodies. Its general solution has not yet been found, while one of those that are particular says that in those cases when such bodies are located on one and the same line or in vertices of equilateral triangles, they move consistently, as if they were bound by some rigid structure. Points of the location of such bodies were called libration points.

Their practical uses drew scientists' attention when automatic lunar probes were laid on the building berths of spaceship "dockyards", and mathematicians were to calculate their path. The calculations featured three bodies that were bound by gravitation, namely the Earth, the Moon and a space vehicle.

If we start moving from the Earth moonwards, then at a distance of 58 thousand kilometres from the destination the vehicle will get into the first libration point. The second libration point is on the same line, but at a distance of 65 thousand kilometres beyond the Moon. On reaching this or that libration point, the space vehicle can move with the Moon and the Earth, as if hovering in one and the same position in respect to these planets.

The unique properties of libration points have not infrequently made the perspectives of their uses seem quite tenable. For instance, by placing space repeaters in them, it would be possible not only to secure radio communication on the whole territory of the Earth, but also between the Earth and the far side of the Moon. These points prove to be quite advantageous for exploring the Sun, stars, interplanetary matter, and relict radio emission...

All this, however, becomes possible only when the space vehicle stays in the libration points for a considerably long time. But to remain in there it will need a certain control means, i. e. rocket engines. This will call for a great amount of fuel, which will tangibly restrict scientific possibilities of the vehicle.

The Soviet specialists advanced a different approach. It consists in attaching this kind of satellite to the Moon by means of a cable. The calculational results prove that the idea is by no means chimerical, as it may seem at first, and that there is every reason to discuss it. They furnish as an example a particular case when the station weighing 2.5 thousand tonnes can be retained near the Moon with a cable up to 100 thousand kilometres long and of only 0.3 square millimetres in cross-section. It is quite natural that such a cable should be spliced of the most modern and superstrong materials. The cable weight will be equal to only a very small part of the mass of the space station itself.

Here is one more suggestion recently submitted by the Soviet scientists and designers to the International Astronautical Federation Congress. The report was entitled "An Unlimitedly Extending Space Telescope".

Radio astronomers avail themselves of every possible means to enhance the sensitivity of their instruments. It is the sensitivity that determines their "scope of the world", the maximum distance at which sources of cosmic radio emission under study can be situated. The greater the antenna area, the more reliable the reception. As a result of the Earth's rotation, objects under observation are continuously changing their positions in the sky, and the antennas must follow them up. Thus, freedom and mobility plus maximum dimensions – such can be only achieved in outer space.

Speaking of an unlimitedly extending structure, the authors of the project do not have in mind any boundless size. Restrictions within reasonable limits are superimposed on the space-borne telescope by the technological possibilities and scientific tasks set before it. However, no one knows if any additional requirements to the size of the instruments will arise with time. But it is "unlimitedly extending", isn't it? Meanwhile, astrophysicists would be

quite content with antennas of 1 to 10 kilometres in diameter.

Why are then radio telescopes of such great dimensions necessary? Two examples may prove to be ample. The Bureau of the Scientific Council concerned with the "Radioastronomy" complex problem of the USSR Academy of Sciences, as far back as in 1974 discussed and approved the research programme pertaining to the communication with extraterrestrial civilizations. To ensure the fulfilment of the programme it was suggested that a system of two radio telescopes spaced apart at a considerable distance should be worked out, the radio telescopes having large full-swing antennas with an area of up to one square kilometre.

One more enticing idea. Space radio telescopes put in interplanetary orbits can help our world acquire a third dimension, so to speak, i. e. for the first time reveal the invisible side of remote celestial objects, thus making them seen as three-dimensional. The Universe surrounding us has always been lop-sidedly turned to us. Irrespective of how we look at it, we see only flat images of the starry sky, reminding us of the canvases in a suite of rooms in an art gallery. It can well be imagined what great significance it will have for the solution of fundamental problems of astrophysics and even of world outlook. Besides, such kind of "radio holography", in the opinion of the well-known Soviet astronomer I. S. Shklovsky, will help to unequivocally solve the problem concerning either artificial or natural origin of this or that "suspicious" source of radio emission.

What does this telescope look like in the imagination of the authors of the project? The spherical bowl of its main antenna must consist of a large number of similar modules. Each of them will have the size of the order of 200 metres. The folded lattice modules will be placed in orbit, where they will automatically unfold and join one

another. The whole framework will be covered with small movable metal screens hinged to it and having an accurately shaped surface. Thus, by turning the screens, it will be possible to change the surface form of the reflecting mirror. The operation must be accomplished both when extending the antenna and when compensating it for deformations resulting from the gravitational forces, light pressure and variations in temperature. In a 10-kilometre antenna the surface deformation as a result of all the factors may be as great as 1 metre.

In radio telescopes, as a rule, the radiation of a celestial source is reflected from the surface of a reflector antenna, and being collected in its focus, falls on a smaller metal mirror that directs the collected energy to a receiver. This is exactly the scheme that has been chosen by the authors of the space project.

However, instead of one auxiliary mirror, the orbital telescope will have three. They will be placed on three independent space vehicles. In operation, the vehicles will hover near the focus of the main antenna, and not on its axis but at small angles to it. This will make it possible to observe at the same time several "radio stations" spaced apart and to diminish the demands to the accuracy in orientation of the main massive mirror.

The control of the receiving space vehicles as well as the form of the antenna's surface will be conducted from a manned station flying near-by.

How do the authors intend to implement their project to practice? Here is one of the variants. At first certain sections and units of the telescope will be put in a lower satellite's orbit. A special orbital tug vehicle will pull together the delivered modules into bundles or "trains", while another, interorbital tug vehicle, will carry them to a higher working orbit. This is where the final assembling will take place. It can be done by either robots or spacemen. It has been estimated that a kilometre-long tele-

scope can be assembled at an altitude of not lower than one thousand kilometres, while an antenna of 10 kilometres in diameter requires an altitude of not lower than 36 thousand kilometres.

In conclusion the authors pointed out that "the solution of engineering problems concerning the development of a space telescope coincides with the basic developmental trend of modern space technology. Similar demands, for example, arise in discussing projects of big solar power stations and large-scale research stations in outer space". These words are signed by prominent Soviet scientists, cosmonauts and designers. This guarantees, beyond any doubt, that the time when unusual structures of immense dimensions will appear in outer space, is not far away.

And now let us penetrate into a more distant future.

... The time of lectures and classes is over. A couple of days ago the commission responsible for providing the graduates of the Higher School for Space Studies with work, offered you a vacancy at the Centre of Interplanetary Flights. Here in the department of space transportations there was a vacancy for a third-class pilot. It would be possible to speak of a second-class only after ten or twenty flights to the Moon or several years of flights between the orbital habitations. The department can boast of quite a few top-class pilots and they are priviledged to be in charge of interplanetary spaceships, supplying the scientific centres on Mercury and Saturn satellites with all the necessities. In their time they too had to deliver to the Moon or Mars hundreds of tourists before they were granted the right to fly to the more remote regions of the solar system.

But there is no ground for frustration. You are still young and the future is with you. It is for you that the automatic probes that have recently reached Pluto are making reconnaissance flights, and it is for you that the

bright-minded robots sent from the Earth are opening new vistas into unknown interstellar space. Or, perhaps, after several visits to Mars, you will want to devote yourself solely to the Red Planet, and will stay there in one of the centres for scientific research. You may also be carried away by the problem pertaining to the communication with extraterrestrial civilizations and you will start preparing for the first flight to the mysterious spot of the Universe from where the signals of cryptic intelligent beings had been issued to us.

However, let us not be carried away too far on the wings of our imagination. Nevertheless, it would not be out of place to bring back into our memory those instances when the actual state of things surpassed the most daring speculations of scientists and science-fiction writers. But it is always necessary to put in a lot of work so as to make a dream come true, and a fair amount of knowledge is required so as to make the work successful. Let us learn for the future, then, and continue learning.

The tomorrow of space science is the fate of all the people on the planet. To make it come closer to us is great honour and responsibility of every individual, group, or nation.

In this country no one ever forgets about it. That is why so much attention is given to exploration and peaceful uses of outer space. Each of us understands how right Konstantin Tsiolkovsky was when he most emphatically said that in the future space efforts "will give people lots of bread and unlimited power".

Unusual Properties of Common Solutions

Yu. FIALKOV, D. Sc. (Chem.)

Unusual properties of solutions in general and those of one of them, viz. water, are described in an easily understandable and fascinating way. Solutions could be encountered everywhere in nature. Air is a solution, a sea wave is also a solution, and a solid mineral can be considered a solution as well.

The reader will learn why solutions boil or freeze, why some substances dissociate into ions when dissolved in liquids, and how an electric current flows through a solution. The major part of the book is devoted to the physical and chemical properties of solutions.

Elementary Order (Mendeleev and His Periodic System)

I. PETRYANOV, Mem. USSR Acad. Sc. and
D. TRIFONOV, D. Sc. (Chem.)

The periodic system of chemical elements has been compared to the multiplication table in view of the essential part it plays in modern chemistry and not only chemistry but many other sciences. But while the multiplication table must be simply learned by heart the periodic system of elements should be first of all understood. One must analyze its structure and understand its regularities and then one can use it as a veritable encyclopaedia of chemical knowledge.
The book has been written specially for teenagers by a well known historian of chemistry and a prominent physical chemist.

Diamonds Wrought by Man

B. DERJAGUIN, Corr. Mem. USSR Acad. Sc. and

D. FEDOSEYEV, D. Sc. (Chem.)

This is a fascinating history of how man has succeeded in synthesizing the diamond, the hardest mineral found in nature. Related in detail are the technologies by means of which diamonds are synthesized at superhigh pressures from solutions of carbon in molten metals and how diamond crystals can be grown from the gaseous phase.

Yuri Veniaminovich Kolesnikov is a popular-science writer whose articles on space research, astronomy, biology and history appear regularly in Soviet newspapers and magazines. He was born in 1935 and graduated from the Moscow Power Engineering Institute in 1959.

Yuri Nikolayevich Glazkov, Cand. Sc. (Eng.), is a well-known Soviet cosmonaut. Born in 1939, he graduated from the Kharkov Higher Air-Force Engineering School in 1962 and served in the Air Force until 1965 when he joined the team of Soviet cosmonauts. Qualified as a pilot, Glazkov has flown on various spaceships and orbital stations. In 1977 he was the flight engineer aboard Soyuz 24 and Salyut 5. Glazkov, who was awarded the title of Hero of the Soviet Union, is currently engaged in scientific research.